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UNIVERSITY OF ALBERTA

Comparative Passage of Northern Pike
(*Esox lucius*) in Standard Denil
and Steeppass Fishways

by

Richard Arthur Orr

©

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
AND RESEARCH IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

DEPARTMENT OF ZOOLOGY

EDMONTON, ALBERTA
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Yours sincerely,

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Mr. C. Katopodis

Joseph S. Nelson

February 4, 1993

Abstract

A standard Denil fishway and a steeppass fishway were operated adjacent to each other at a marsh in east-central Saskatchewan to determine how effectively these designs pass northern pike. Both fishways consisted of three sections from 8.2 to 10.4 metres in length at slopes of 10%. A total of 87 pike ascended the two fishways during the study in the spring of 1990. The fishways were operated at two flows, .045 m^3/s (.25 m depth) and .1 m^3/s (.41 m depth). Pike were equally capable of ascending both fishways at both flow regimes. However, under the high flow regime, when pike were allowed to choose between fishways at the entrances, more pike ascended the steeppass fishway than the standard Denil fishway. There was no difference in the number of ascents at low flows.

The channel downstream of the fishways was blocked with a two-way trap to monitor fish movements in the vicinity of the fishways. Forty-nine pike were tagged as they entered the study area and were later recaptured. Of these, twelve ascended the steeppass fishway and seven ascended the standard Denil fishway for an aggregate passage efficiency of 39%. The highest passage rate observed was in the steeppass fishway at the high flow regime, with an efficiency of 32%.

There were no differences between fishways with respect to length, sex or spawning condition of ascending pike. Average size of pike that ascended the fishways was less

than pike that did not ascend the fishways. There was no difference between ascending and nonascending pike with respect to sex or spawning condition. Pike ascended the fishways with little delay after they entered the fishway area, with a median delay time of 2.75 hours.

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LIST OF SYMBOLS

bo	clear width of fishway
g	acceleration due to gravity (9.81 m/sec^2)
Q	discharge
Q*	dimensionless discharge, equal to $Q/\sqrt{gSob^5}$
So	bed slope of fishway
u	time averaged longitudinal velocity
um	velocity scale for steeppass fishway
u'm	velocity scale for standard Denil fishway
U	depth averaged velocity
y	distance above bed of fishway
yo	depth of uniform flow

1. Introduction

Migrations commonly occur among various species of fish and include the movement of fish to feeding areas, movement of adult fish to spawning areas and movement to areas with more hospitable conditions (Jens 1973). These migrations can be disrupted or blocked by natural obstructions such as rock slides or waterfalls or by man-made obstructions, such as dams or weirs (Clay 1961). A properly designed and installed fishway allows passage of fish past these obstructions.

Considerable research has been conducted on the effectiveness of fishways but work has been mainly concentrated on facilities designed for anadromous species such as salmon (NTIS 1983). Field evaluations of fishway installations provide the best means of furthering our understanding of fishway function (Collins and Gillis 1985) yet few studies have been conducted on the success and suitability of different fishway designs for fish species common to the prairie region.

In the spring of 1989 and 1990, a study was conducted to compare the performance of two types of fishways, the standard Denil and the Alaska steeppass Denil. These were installed and operated at a water control dyke forming part of the Siisiip Marsh complex developed by Ducks Unlimited (Canada) in the Cumberland Delta of east-central Saskatchewan (Figure 1).

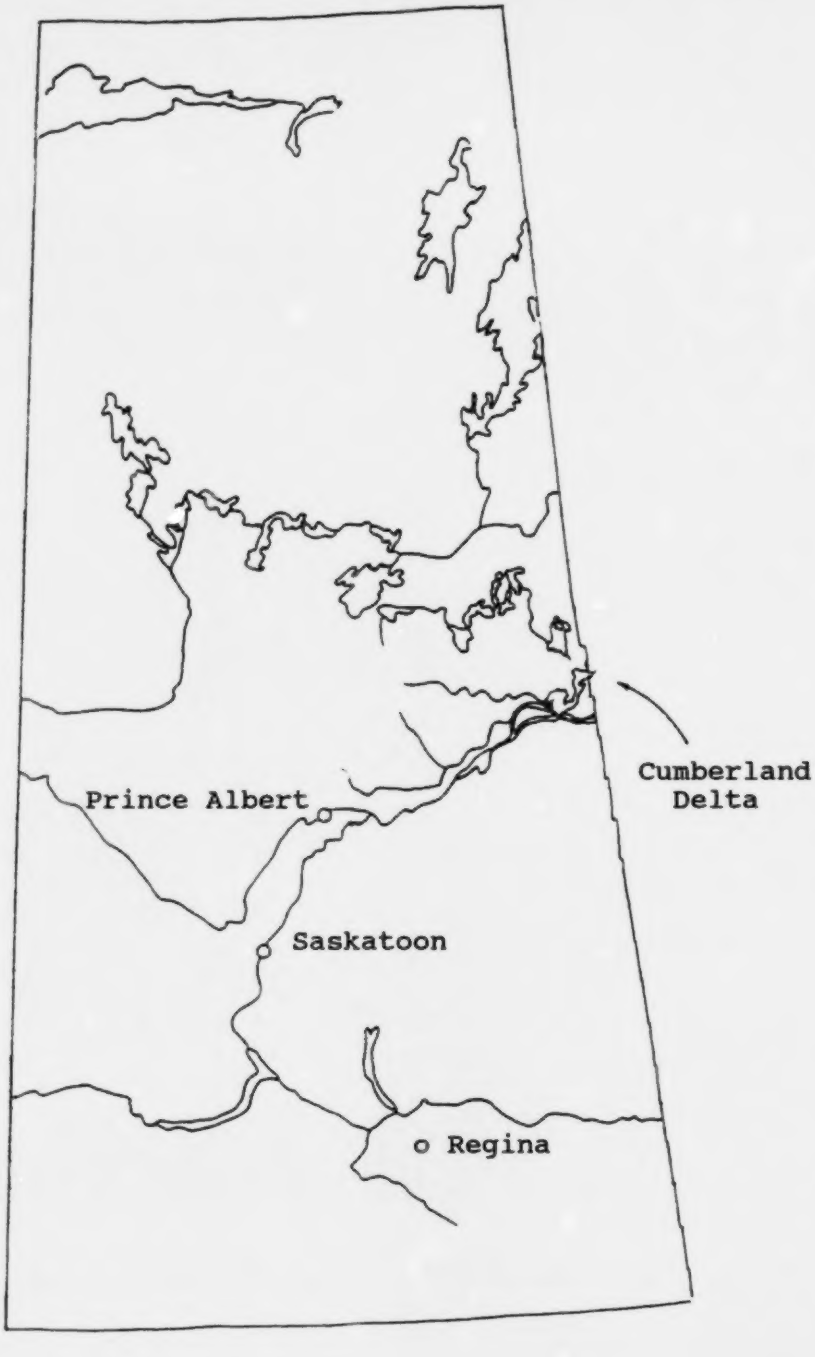


Figure 1. Map of Saskatchewan showing the location of the Cumberland Delta.

The Siisiip fishways are located adjacent to each other at the upstream end of an access channel connecting the Centre Angling River to the Dumbell-Knudsen Marsh which constitutes the western portion of the Siisiip Marsh complex (Figure 2). The Dumbell-Knudsen Marsh area had historically been used by northern pike for spawning and the fishways were installed to ensure continued access by spawners. Installation of these fishways provided an opportunity to compare their performance and efficiency with respect to northern pike.

2. Fishway Design and Function

A fishway is defined by Clay (1961) as "a water passage around or through an obstruction, so designed as to dissipate the energy in the water in such a manner as to enable the fish to ascend without undue stress". The energy of moving water is dissipated in the fishway by friction along the boundary of the channel or by abrupt changes in magnitude or direction of flow (Collins and Gillis 1985). Water velocities can thus be kept within the capabilities of the fish. A successful fishway should attract fish, allow them to enter and exit without delay, maintain suitable hydraulic conditions for the species of concern, permit exit without danger of being swept back and accomplish this without undue cost (Katopodis 1981).

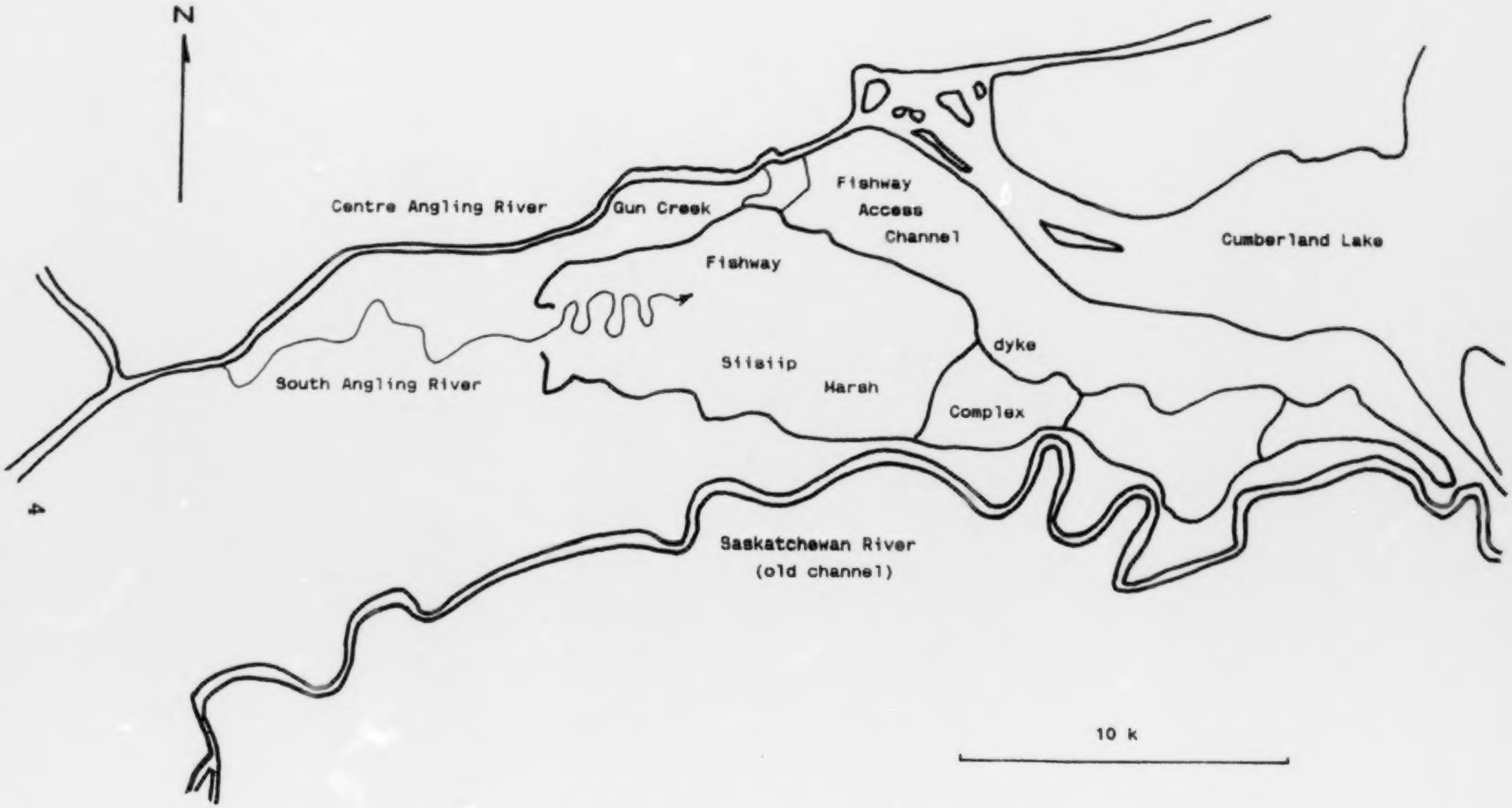


Figure 2. Location of Siisiip fishways in the Cumberland Delta.

2.1 Types of Fishways

Numerous types of fishways exist but most fall into three broad categories: pool and weir, vertical slot and Denil (Katopodis 1981). The pool and weir is the traditional fish ladder consisting of a series of stepped pools with water flow controlled by weirs (Figure 3). Vertical slot fishways consist of a sloping channel divided into pools. Pools are joined by one or two vertical slots which direct the flow of water against the wall of the next pool (Figure 4). The Denil fishway consists of a rectangular flume with baffles that redirect the flow of water back onto itself (Figure 5) (MacLeod & Nemenyi 1941, Katopodis and Rajaratnam 1983).

Pool and weir fishways have been used successfully for salmon, trout and other species that will readily swim or leap over weirs (Katopodis 1981). They offer a wide zone of passage (Collins and Gillis 1985) but operating problems can be encountered with fluctuating headwater levels (Bell 1986, Katopodis 1981).

Vertical slot fishways have good energy dissipating properties, offer a deep zone of passage (Collins and Gillis 1985) and can accommodate wide fluctuations in water level (Katopodis 1981).

Denil fishways have excellent energy dissipating properties allowing construction at steep slopes (Ziemer 1962) and have good entrance attraction for fish due to the

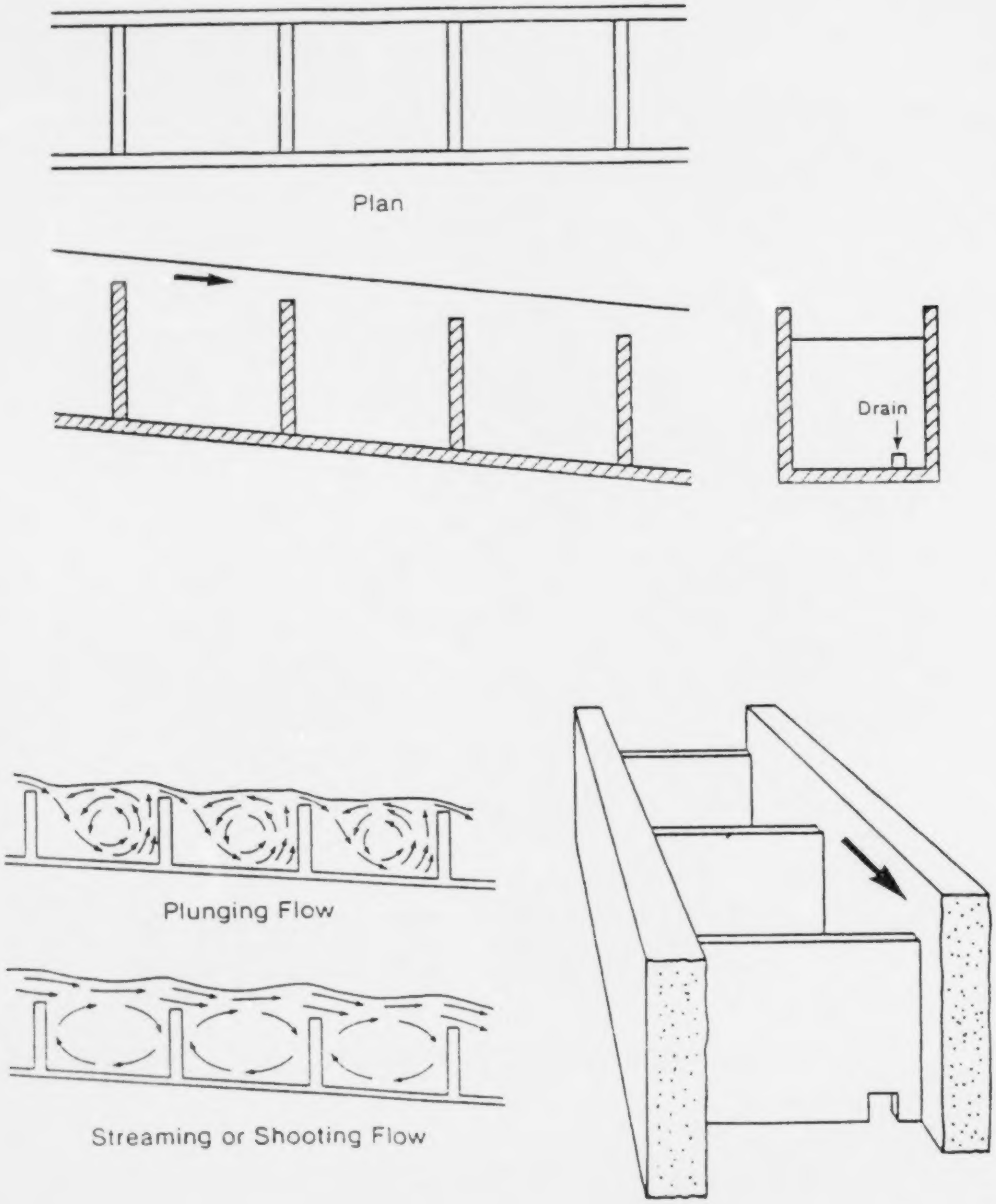


Figure 3. Pool and weir fishway (from Katopodis 1981)

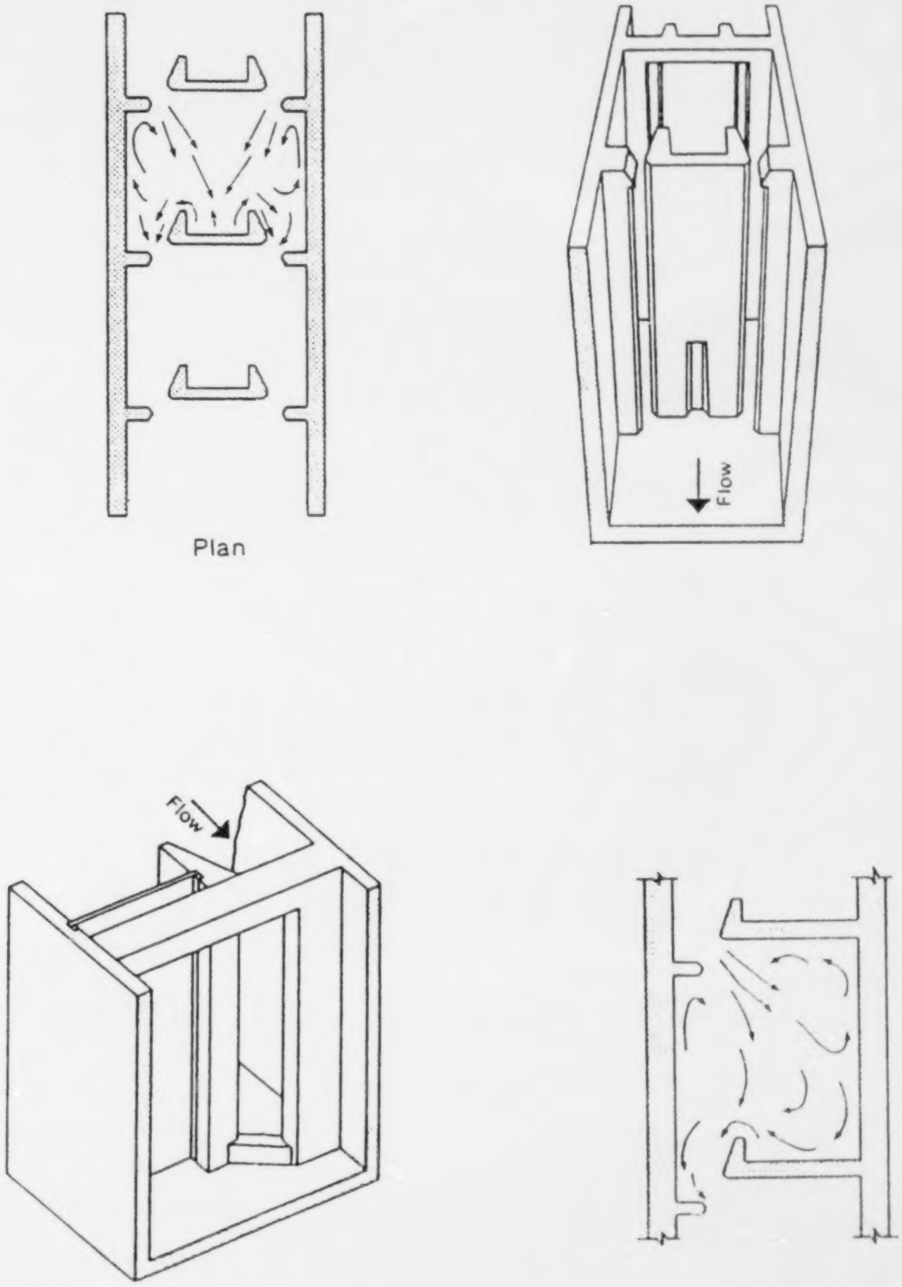
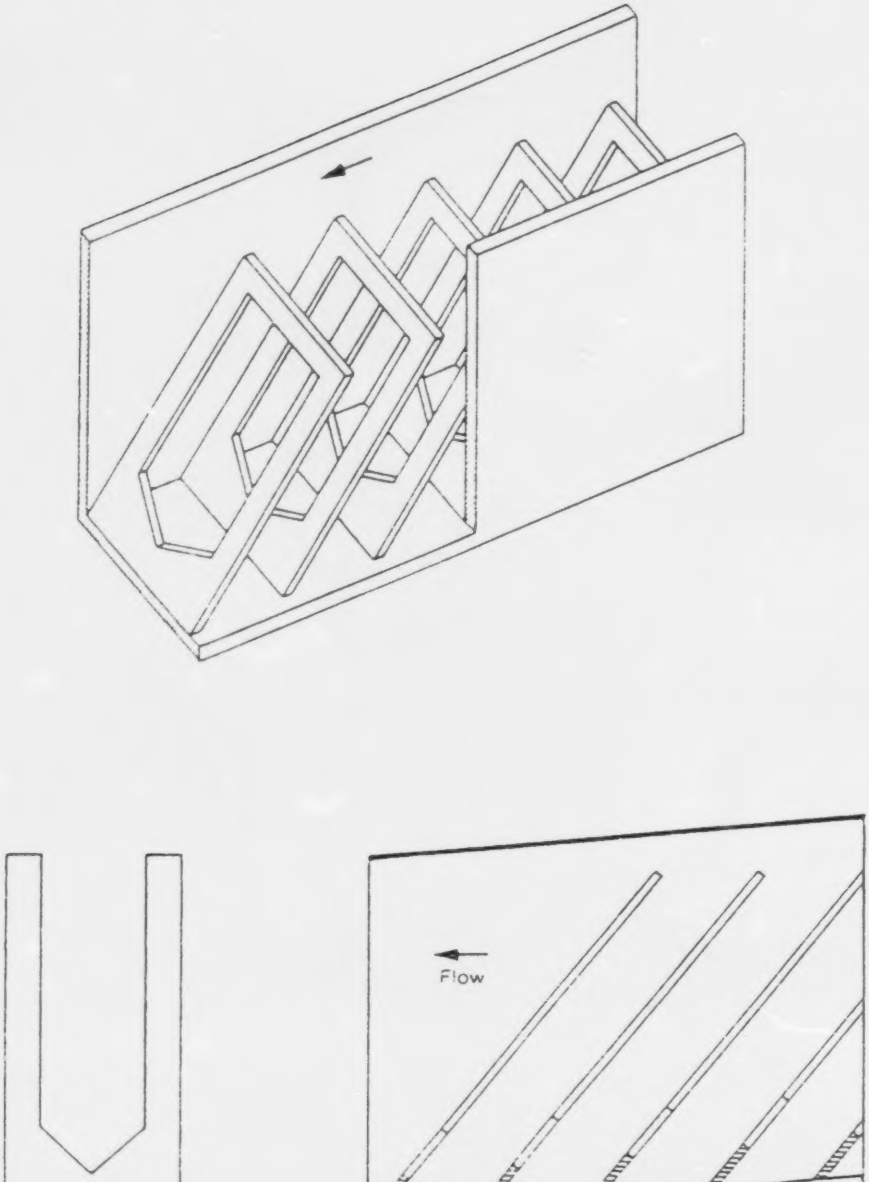


Figure 4. Vertical slot fishways. Double slot design above, single slot design below (from Katopodis 1981)



Baffle Detail

Longitudinal-Section

Figure 5. Standard Denil fishway (from Katopodis 1981)

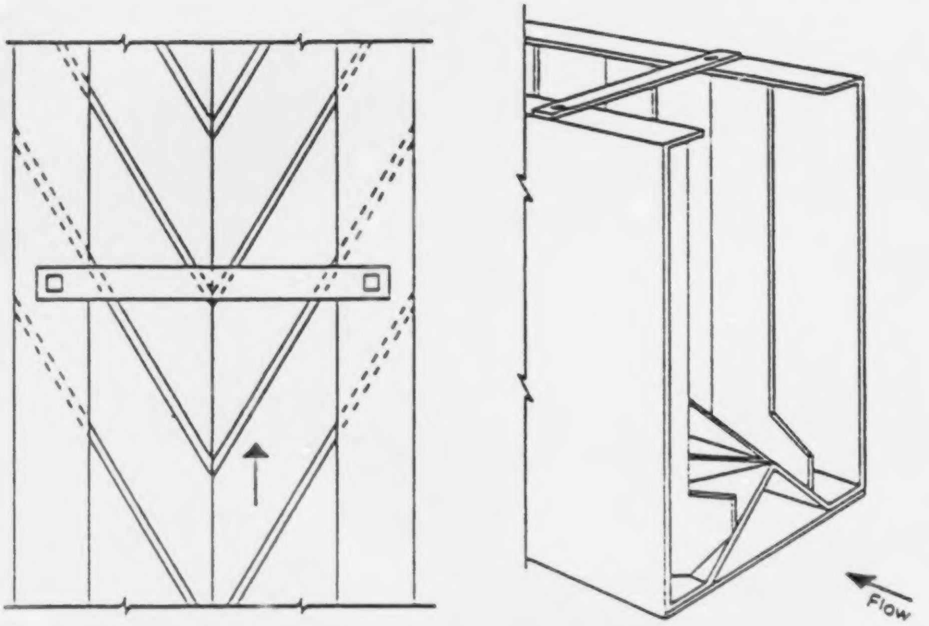
high volume of water carried. Denil fishways also offer a range of water velocities against which fish may swim.

Energy dissipation occurs at discrete intervals in the pool and weir and vertical slot fishways by means of turbulence in the pools. In the Denil fishway, energy dissipation occurs throughout the length of the fishway by redirection of the water flow (Tomich et al. 1982).

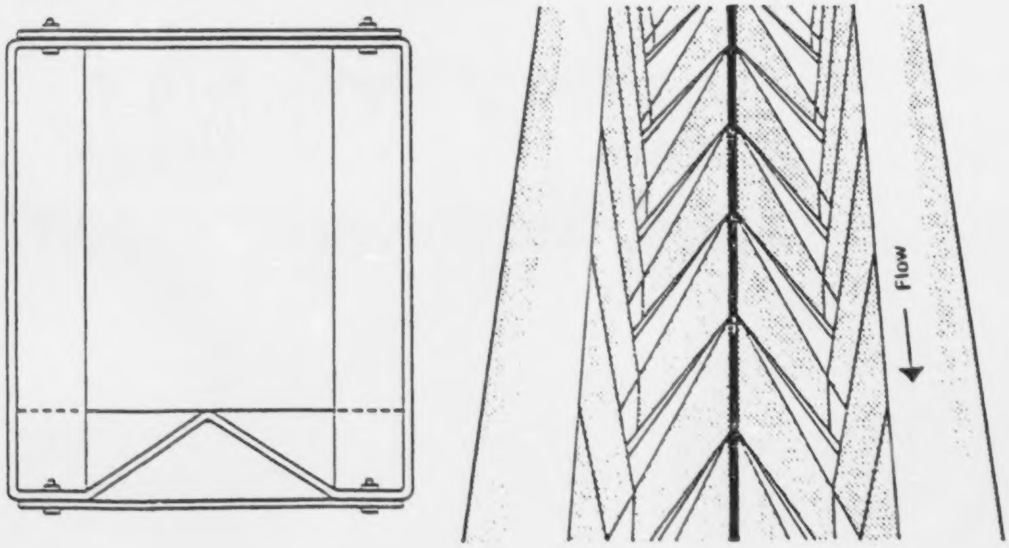
2.2 Denil Fishways

Two major variations of the Denil fishway exist (Katopodis and Rajaratnam 1983). The standard Denil fishway, also known simply as the Denil, is very similar to a design adopted by the Committee on Fish Passes of the British Institute of Civil Engineers (Katopodis and Rajaratnam 1983). In this design, planar baffles of standard proportions are set into a flume at a 45 degree angle into the flow (Figure 5). The Alaska steeppass design (Ziemer 1962), referred to hereinafter as the steeppass, has a complex baffle configuration set perpendicular to the flow (Figure 6). The standard Denil and steeppass fishways are both efficient energy dissipators, with mean centreline water velocities of 11% and 14%, respectively, of expected velocities in flumes without baffles (Katopodis and Rajaratnam 1983).

The different baffle configurations of the two designs result in significantly different flow patterns and velocity



Plan



Cross-Section

Figure 6. Steeppass fishway (from Katopodis 1981)

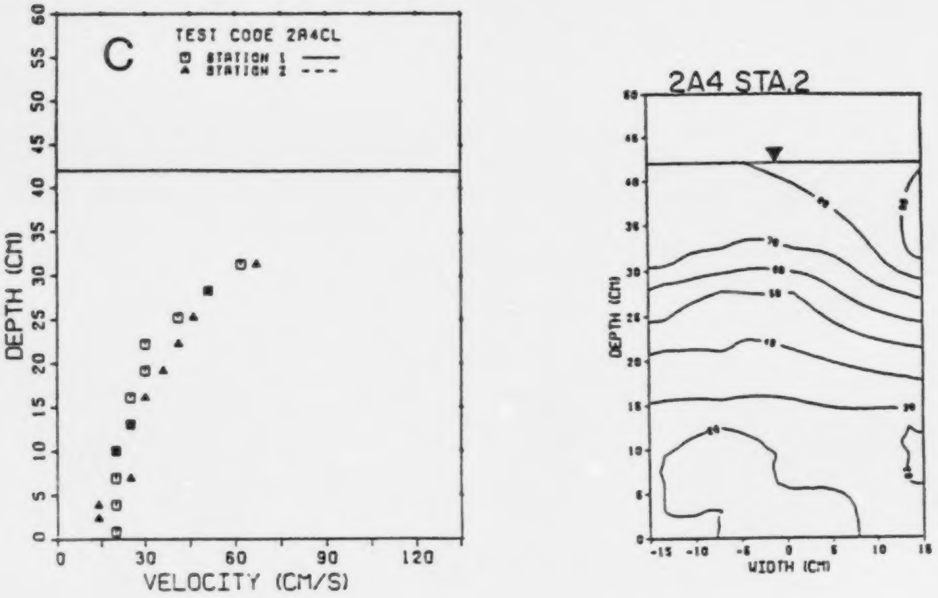
regimes within the water columns (Rajaratnam and Katopodis 1983). The standard Denil fishway exhibits low but constant velocities from the floor of the fishway up to a certain depth, then increasing velocities to the surface (Figure 7). Conversely, the steeppass design results in high water velocities near the bottom and decreasing velocities towards the surface (Figure 7), provided the ratio of depth to width of flow (y_o/b) remains less than about 2.0 (Rajaratnam and Katopodis 1991).

3. Fishway Studies

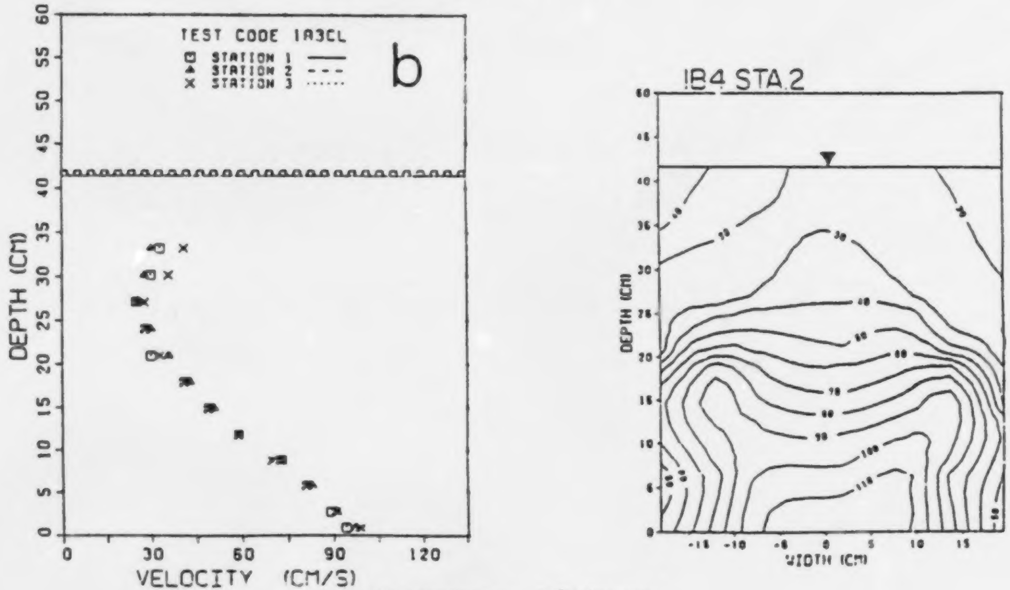
3.1 Suitability of Fishway Design to Capabilities of Fish

Different species of fish have different swimming abilities (Beamish 1978, Jones et al. 1974) and exhibit differences in behaviour (Katopodis 1981). To be successful, a fishway must produce hydraulic conditions suited to the swimming capabilities and behaviour of the intended fish species. It is therefore important that various fishway designs be evaluated for their suitability for different species.

Relatively few studies have been conducted on fishway passage of north-temperate freshwater fish (NTIS 1983). Carp (*Cyprinus carpio* L.), buffalofish (*Ictiobus cyprinellus*) and various sucker species readily ascended Denil fishways (McLeod and Nemenyi 1941, Einer 1944, Harrison 1948, Harrison and Speaker 1950, Fernet 1984, Tack



Standard Denil Fishway



Steeppass Fishway

Figure 7. Left - Velocity profile of vertical axis at centre of fishway channel. Right - Velocity isotachs (cm/sec) of vertical cross-section of fishway channel (from Katopodis and Rajaratnam 1983)

and Fisher 1977, Katopodis et al. 1991) and vertical slot fishways (Dunn 1983, Tomich et al. 1982) but did not ascend pool and weir fishways as successfully (McLeod and Nemenyi 1941, Minchau 1980). Good passage success was determined for walleye (*Stizostedion vitreum* Mitchill) and sauger (*Stizostedion canadense* Smith) in Denil fishways in western Canada (Katopodis et al. 1991) and for Arctic grayling (*Thymallus arcticus* Pallus) in a steeppass fishway in Alaska (Tack and Fisher 1977). Passage success for northern pike has generally been poor depending on fishway type. Low passage rates have been observed in pool and weir fishways (Minchau 1980, Tomich et al. 1982, Watters 1980) and vertical slot fishways (Dunn 1984). Passage success of northern pike in Denil fishways varies from poor to fair (Halstead 1984, Fernet 1984, Tomich et al. 1982).

3.1.2 Suitability of Fishway Designs for Northern Pike in the Prairie Region

3.1.2.1 Pool and Weir Fishways

Evaluations of two pool and weir fishways in Alberta suggest that these facilities are unsuitable for northern pike. A tagging study at the Fawcett Lake pool and weir fishway in 1979 estimated that only 0.2% of available pike actually ascended through the ten pools (Minchau 1980). In 1981, only one of twelve available pike ascended (Tomich et al. 1982). A smaller pool and weir fishway at Gregoire Lake had a passage rate of only 6.4% for northern pike (Watters 1980). Minchau (1980) suggested that excessive water velocities (1.21 m/sec) at the weirs impeded passage, however, Nelson (1983) found that pike had no difficulty in surmounting weirs against velocities of 3.0 m/sec. Possibly, pike do not ascend pool and weir fishways due to behavioural reactions to weirs. In addition to the design itself, low attraction flows and poor siting of the fishway entrances may have contributed to poor pike passage in pool and weir fishways (Minchau 1980, Tomich et al. 1982).

3.1.2.2 Vertical Slot Fishways

Dunn (1983) monitored fish ascents at a thirteen bay vertical slot fishway at Katepwa Lake in Saskatchewan. Thousands of fish, mainly white suckers (*Catostomus commersoni* Lacépède) and carp, ascended. Less than one per cent of ascending fish were northern pike. No estimate could be made of the number of pike attempting to ascend so its effectiveness for this species was not determined. Passage was probably reduced by the presence of competing attraction water from a nearby channel (Dunn 1983).

A comparative study of a six bay vertical slot fishway and two Denil fishways at 10% and 20% slopes was conducted at the outlet of Lesser Slave Lake in Alberta (Schwalme et al. 1985). Fewer pike ascended the vertical slot fishway relative to the Denil fishways, suggesting that the vertical slot fishway is not well suited for pike.

3.1.2.3 Denil Fishways

Evaluations of standard Denil fishways at several locations in the prairie provinces suggest that these are suitable for passage of northern pike. No studies of pike passage at steeppass fishways are available.

A Denil fishway at Fawcett Lake, Alberta, passed 123 northern pike. Of 802 pike tagged below the fishway, only 18 ascended, for an efficiency of 2.3%. However, poor passage may have been due to low water levels in the fishway, poor entrance location and competing flow from a nearby weir (Halstead 1984). Modifications to the entrance and higher water levels increased the estimated efficiency to 10.4% the following year (Fernet 1984).

Large numbers of pike were observed ascending a Denil fishway at Cowan Lake, Saskatchewan (Katopodis et al. 1991). Over a three week period in 1985, approximately 6600 pike ascended. Although no efficiency estimate was made, the high numbers suggest that this design is compatible with pike requirements.

A small Denil fishway on the Wilson River in Manitoba initially showed poor results for northern pike (Tomich et al. 1982). Only one of twenty pike attempting to ascend actually succeeded. Poor success was attributed to unsuitable entrance conditions. A total of 73 pike were captured and placed in the fishway channel at water velocities ranging from .2 m/sec to .6 m/sec. Passage efficiency within the fishway ranged from 14.3% at high flows to 55.6% at intermediate flows.

A comparative evaluation of two Denil fishways and a vertical slot fishway was conducted at Lesser Slave Lake in 1984 (Schwalme et al. 1985). Few pike were available for ascent, but the study demonstrated a preference by pike for the Denil fishways.

These studies suggest that when entrance conditions are acceptable, Denil fishways provide suitable conditions for passage of northern pike.

4. Study Objectives

Field evaluations of fishways provide the best means of increasing our understanding of fishway function (Collins and Gillis 1985). However, relatively few studies have been conducted on the suitability of fishways for north-temperate freshwater fish. Some studies have examined passage of northern pike at standard Denil fishways (Fernet 1984, Halstead 1984, Katopodis et al. 1991) but none have considered the use of steeppass fishways by this species. Few studies have determined realistic efficiency estimates, that is, an estimate of the number of fish ascending a fishway relative to the number below the fishway available for ascent. Only a few studies have made direct comparisons of performance of two types of fishways at the same location (Schwalme et al. 1985, McLeod and Nemenyi 1941, Smith 1985) and there have been no comparative studies of standard Denil and steeppass fishways.

This research examined the performance of a Denil fishway and a steeppass fishway with respect to northern pike. Specific objectives were:

(1) To compare the performance of standard Denil and steeppass fishways. Comparisons between fishways of northern pike passage were made at two different flow regimes.

(2) To relate fish passage to flow conditions in the fishways. For each fishway, comparisons were made of pike passage at two flow regimes.

(3) To estimate the passage efficiency of these fishways. A comparison was made of the number of pike that actually ascended the fishways to the number of pike that were available for ascent below the fishways.

(4) To determine if the fishways select for passage of fish based on physical characteristics of the fish. Comparisons of length, sex and spawning condition were made between fish that ascended the fishways and fish that did not ascend the fishways.

5. Methodology

5.1 Procedures

5.1.1 Fish Sampling

5.1.1.1. Live Sampling

Before handling, all fish were anaesthetized with a solution of 2-phenoxyethanol mixed at approximately 30 ml to 35 litres of water. After sampling, fish were placed in a tub of clean water until fully recovered (usually about five minutes) and then released.

Fork length was determined for all fish by measurement on a wooden measuring board graduated in 2mm increments.

Weight was determined for approximately every third fish sampled. Small fish were weighed with a 2000 g O'Haus spring scale and larger fish with a 27 kg Hanson Model 603 scale. Small fish were weighed to the nearest 25 g and larger fish were weighed to the nearest 100 g. Scales were periodically calibrated with standard weights. All fish were placed in plastic or nylon mesh bags to avoid injury during the weighing procedure.

Sex was determined whenever possible by expression of sexual products. In addition, white suckers were identifiable as males by the presence of nuptial tubercles on the fins.

Spawning condition was determined by the amount and ease of expression of sexual products when the fish were gently stroked posteriorly along the abdomen and by general abdominal condition. Four categories of spawning condition were noted.

(1) Green - no sexual products expelled, abdomen firm.

(2) Expressing - gentle pressure produced a small amount of sexual products.

(3) Ripe - considerable amount of sexual products expelled from gentle pressure on abdomen or from handling the fish.

(4) Spent - no sexual products expelled, abdomen flaccid.

In some cases, difficulties were experienced in distinguishing between green and spent pike on initial capture. Frequently, this condition could be either confirmed or modified by examination of the fish on subsequent captures.

5.1.1.2 Destructive Sampling

A small number of white suckers leaving the study area were destructively sampled to confirm sex and spawning condition determined from external examinations. Pike were not destructively sampled due to the relatively small numbers in the study area.

5.1.1.3 Tagging

Immediately after anaesthetizing, a numbered Monel tag was attached to the left operculum of each fish. Tags were imprinted with the letters SPRR (for Saskatchewan Parks and Renewable Resources) to assist the public in reporting captured fish.

5.1.2 Physical Parameters

5.1.2.1 Water Temperature

Water temperature was measured with an Ertco Model P9367 thermometer. Temperatures were measured in the Centre Angling River at mid-afternoon to represent the maximum daily temperature in the river system. Early morning and evening readings were taken in the fishway channels to approximate the minimum and maximum daily water temperatures at the fishways.

5.1.2.2 Headwater and Tailwater Elevations

Permanent staff gauges were installed by Ducks Unlimited (Canada) at the upstream and downstream ends of the fishways and the geodetic elevation determined for the base of each gauge. Water elevations were recorded at 7:00 AM and 7:00 PM daily. Levels were recorded as feet above sea level and later converted to metres above sea level.

5.1.2.3 Fishway Depths, Discharges and Water Velocities

Depths of flow were determined by measuring from the top of the fishway to the water surface. This measurement was subtracted from the total fishway depth to provide a value for water depth. Measurements were made at three locations on each section of the fishway - two metres from the lower end, midway, and two metres from the upper end. Measurements were made at the beginning and end of each trial period and averaged to provide an overall mean depth of flow for the period. The mean depth of flow was then used to calculate discharge and velocity values.

Due to backwater effects, only the uppermost sections of the fishways had uniform flow conditions throughout the study. Discharge and velocity calculations were therefore restricted to these sections.

Formulae developed by Dr. N. Rajaratnam of the University of Alberta and C. Katopodis of the Freshwater Institute in Winnipeg were used to calculate the discharge Q and local velocities u. Depth averaged velocities U were then calculated from local velocities. Calculations of local velocities and depth averaged velocities were carried out by C. Katopodis at the Freshwater Institute, Winnipeg. Formulae are contained in Appendix 1.

5.2.2 Design of Fishways

Both fishways consisted of three sections of channel separated by stilling basins or resting pools. The fishways were immediately adjacent with a common centre wall on the channel sections and removable plank dividing walls in the resting pools (Appendix 2, Plates 1 to 4).

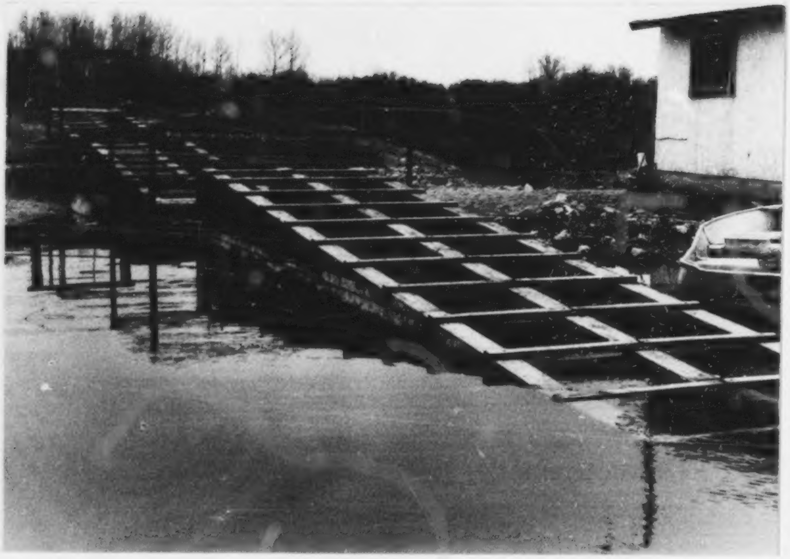


Plate 1. General view of Siisiip fishways. Standard Denil fishway on left, steeppass fishway on right.

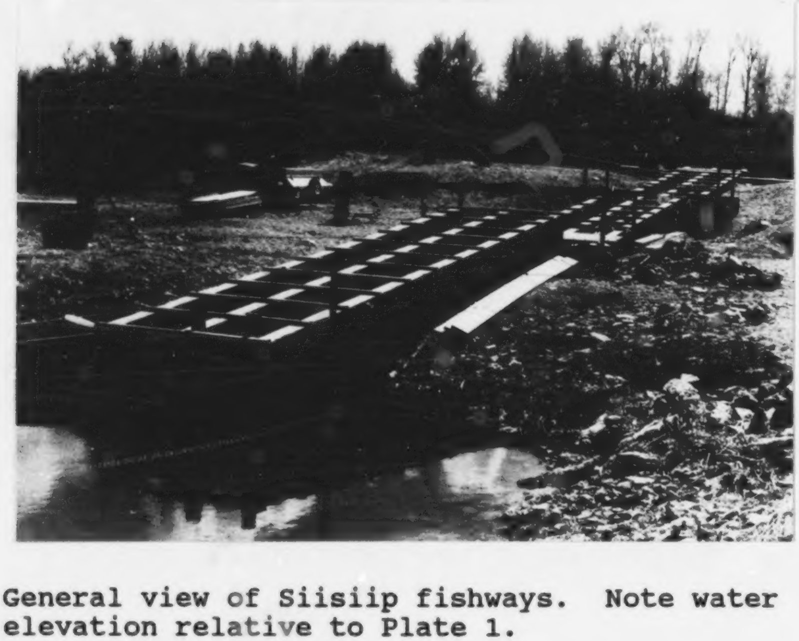


Plate 2. General view of Siisiip fishways. Note water elevation relative to Plate 1.

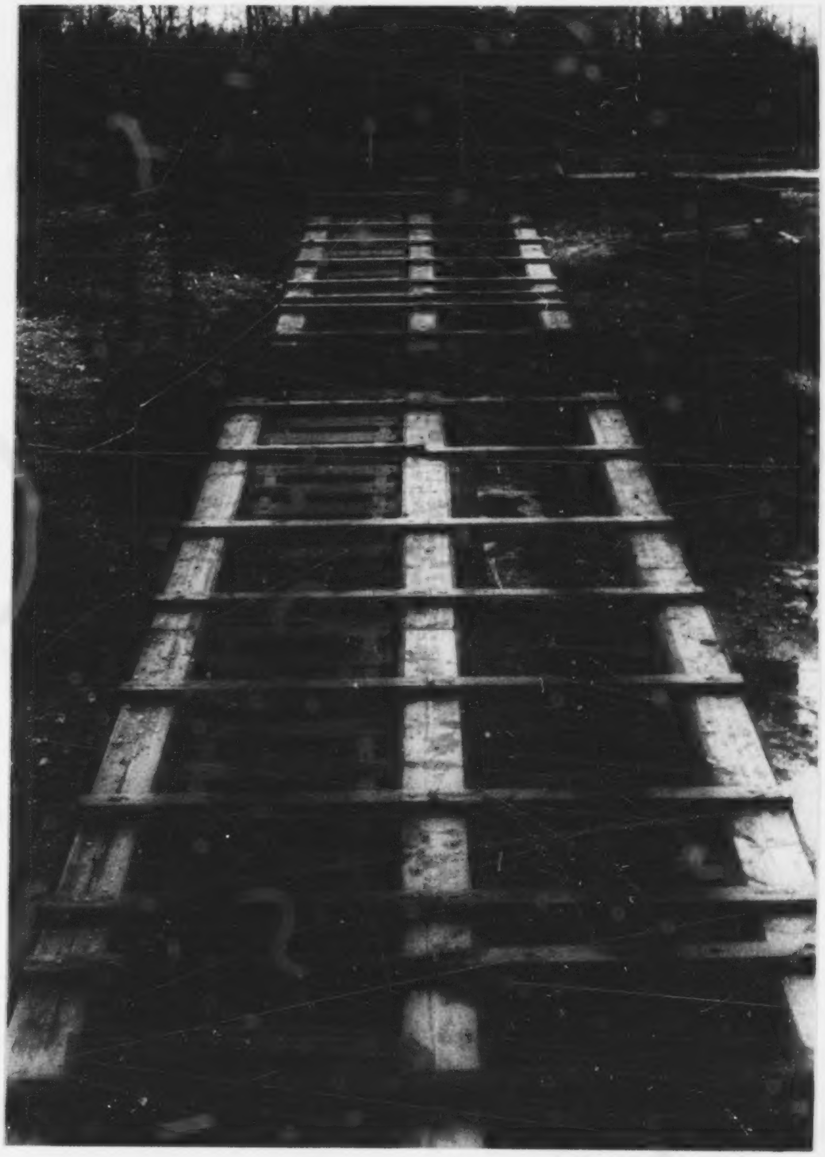


Plate 3. Upper portion of Siisiip fishways showing channels and upper resting pool. Standard denil fishway on left, steeppass fishway on right.

Plate 4. Upper resting pool, looking downstream into standard Denil channel. Note plank dividing wall on left.

The lowermost channel of each fishway was 10.4 metres in length. The middle and upper sections were both 8.2 metres in length. The lower section was 2.0 metres deep whereas the other sections were 1.53 metres deep. All sections were .71 metres in width. The slope was 10% throughout the fishway. Resting pools were 2.74 metres long, 3.73 metres wide and 3.0 metres deep.

Elevation of the fishway floor was 265.85 m ASL at the entrance and 268.53 m ASL at the exit for an elevation difference of 2.68 metres.

The fishways were constructed entirely of treated lumber while the resting pools were sheet piling with rock bases.

Baffles were placed in the standard Denil fishway at 30 cm intervals at an angle of 45 degrees to the floor (Plate 4). Baffles were placed in slots for easy removal and built to standard dimensions (Appendix 3).

The steeppass baffles were constructed from two components. The inverted V and fins of the base were constructed of welded metal and bolted to the fishway floor whereas baffles were constructed of treated plywood set into top and bottom plates. These units were bolted to the floor in alignment with the metal fins of the base (Plate 5). All components were built to standard dimensions (Appendix 3).

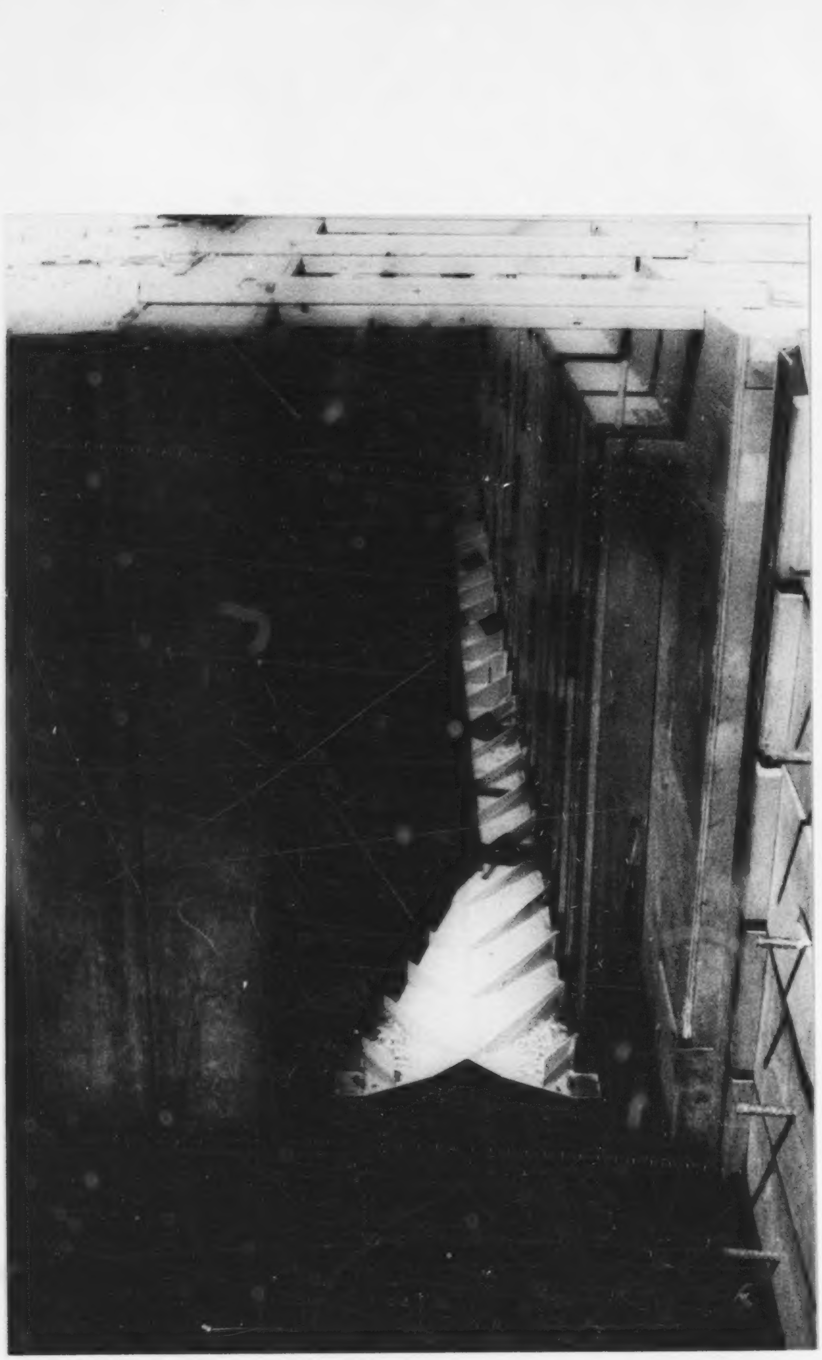


Plate 5. Construction details of steeppass fishway showing metal fins bolted to fishway floor and wood baffles fastened to fishway walls.

5.2.3 Design of Fishway Exit Traps

Traps were placed at the exits of the upper sections of both fishways. Exit traps were constructed of 38mm tubular steel frames and expanded steel mesh measuring 55mm x 20 mm (Plates 6 and 7). Cages were 1.870 metres long, .775 metres wide, and 1.530 metres deep. The front of the traps (adjoining the fishway exit) were equipped with hinged gates which closed to a minimum opening of 26 cm. The gates were extended by the addition of flaps of 1/4" Vexar plastic mesh. The flaps overlapped slightly to allow fish to push them open to enter the trap but prevented subsequent escape.

Modifications were made to the traps to allow control of water flow through the fishways. Plywood sheathing of .64 cm thickness was wired to the bottom of the cages and to both sides to a height of .75 metres (about .15 metres above the water level). The ends opposite the gates were equipped with slots to accept 44 mm wide wooden bars. The volume of water entering the cages and subsequently the fishways was controlled by adjustment of the number and sizes of bars in the slots (Plate 8).

5.2.4 Counting Fence

A counting fence was installed in the fishway access channel approximately 50 metres downstream of the fishway. Depth at the centre of the channel varied from 2.4 metres to 1.2 metres depending on tailwater elevation.

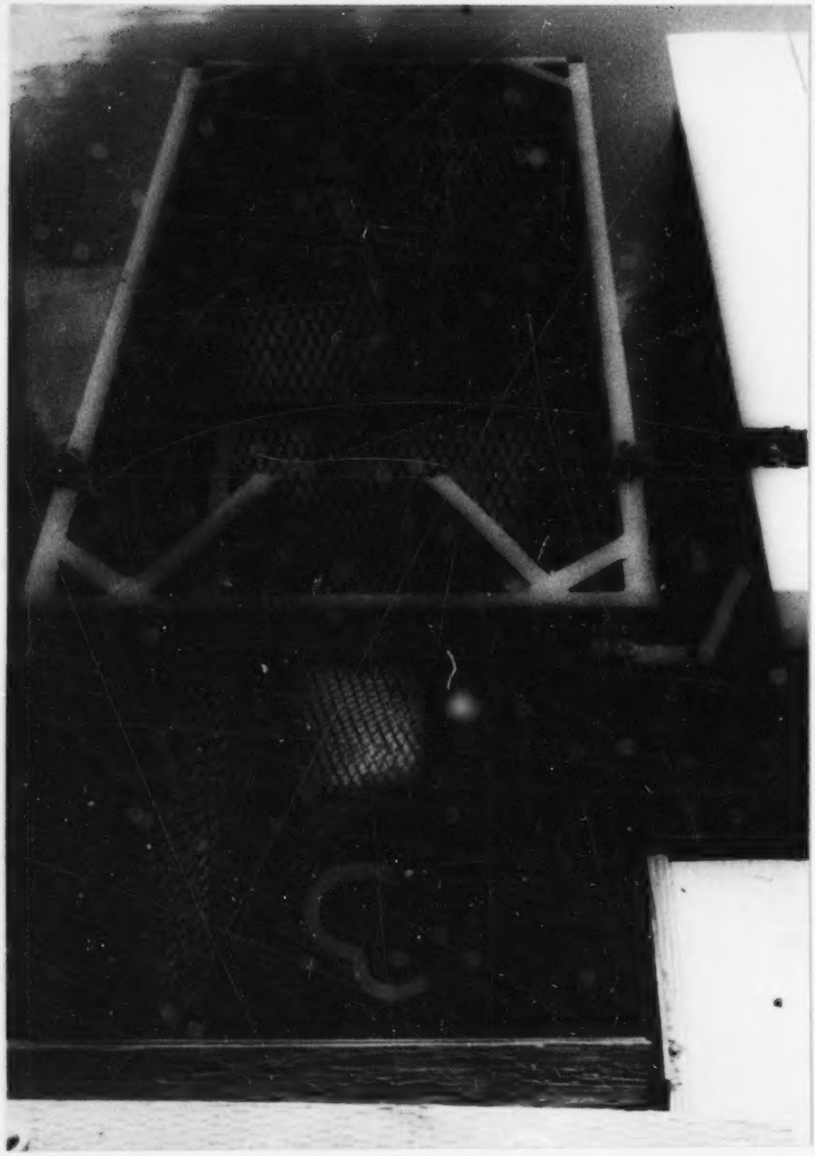


Plate 6. Exit trap at upper end of standard Denil fishway.

Plate 7. Exit traps at upper end of fishways.

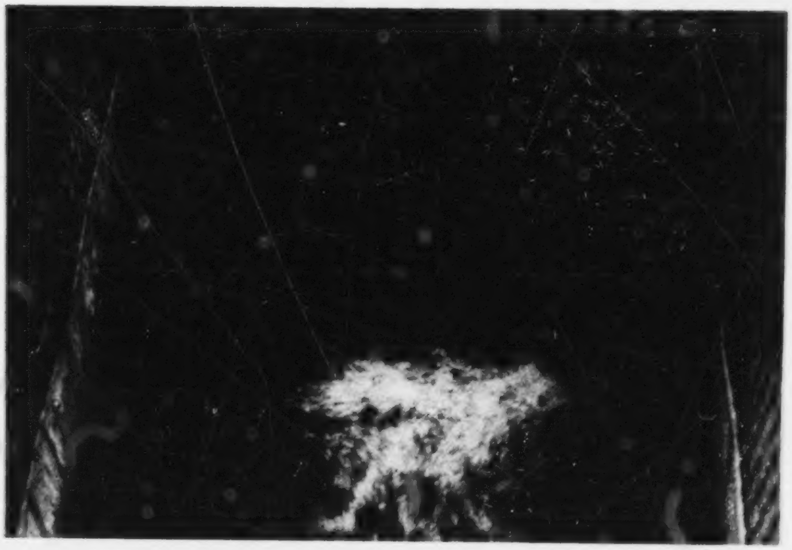


Plate 8. Exit traps showing control of water flow by placement of drop bars.

The counting fence consisted of an upstream trap 3.6 metres square and 2.4 metres deep and a downstream trap three metres square and 2.4 metres deep, connected to each other and to both banks by 2.4 metre deep leads (Figure 8, Plates 9 to 11). Trap material was 1.3 centimetre square nylon mesh whereas material for leads was 2.5 centimetre square nylon mesh. Traps and lateral leads were secured by wooden posts driven into the channel bottom. Post ends approximately ten centimetres in diametre were tied to the tops of the centre lead to allow it to float with fluctuating water levels. All leads and trap entrances were securely sealed to the channel bottom with rocks. With this arrangement of traps and leads, fish moving upstream in the access channel were guided into the upstream traps whereas fish moving downstream out of the area were captured in the downstream trap. This allowed a continuous record to be maintained of fish in the pool area below the fishways.

5.2.5 Operation

5.2.5.1 1989 Study

The exit cages and counting fence were installed as described in Sections 5.2.3 and 5.2.4. The upstream trap was checked once daily at 7:00 AM for fish captures. Tagging and measurements were carried out as described in Section 4.1.2 and all data recorded. Fish were released upstream into the pool. The downstream trap was checked for

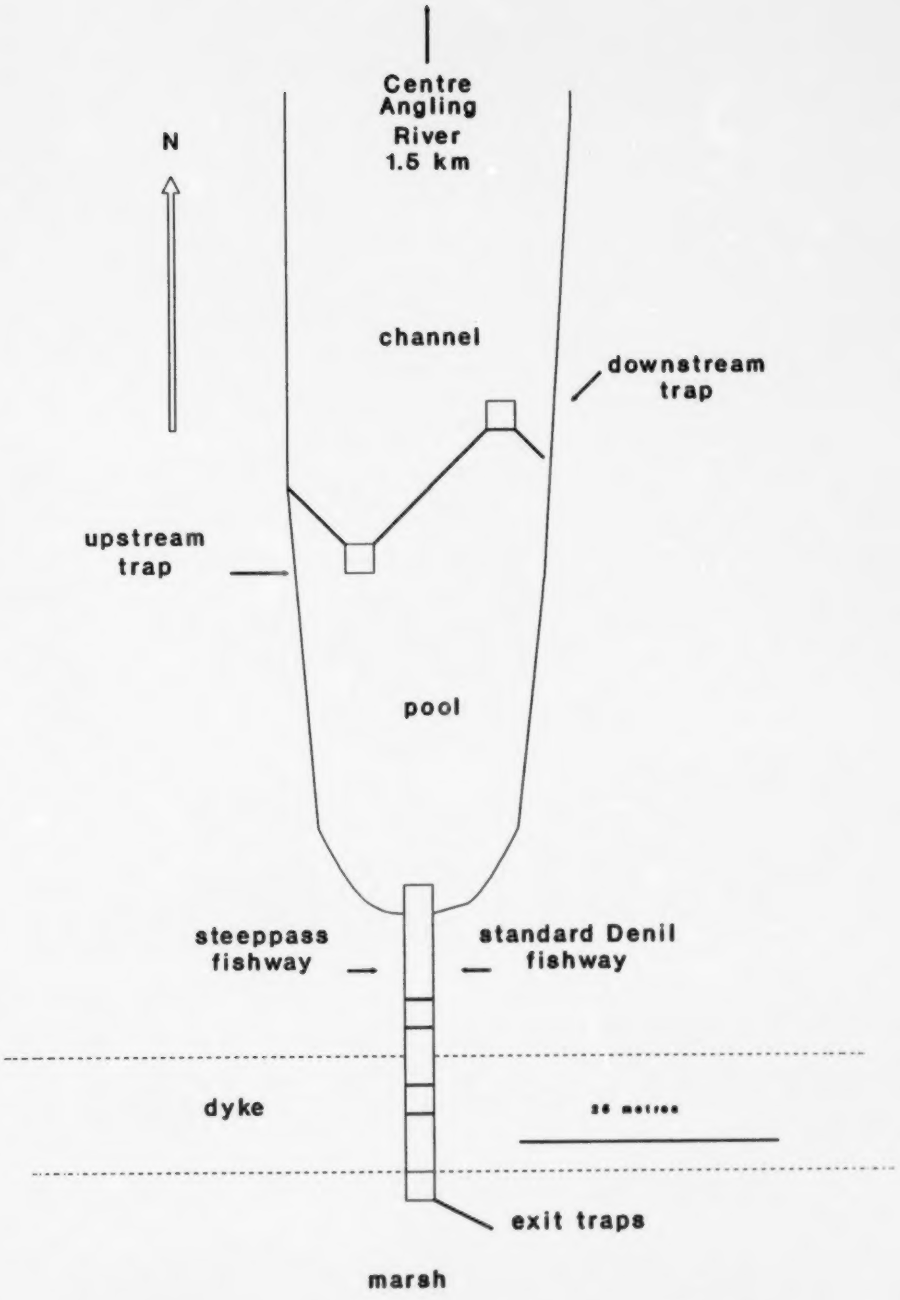


Figure 8. Layout of Siisiip fishways study area.

Plate 9. Counting fence showing downstream trap in foreground, upstream trap in background.

Plate 10. Counting fence with upstream trap.

Plate 11. Counting fence and access channel to Centre Angling River.

fish captures twice daily at 7:00 AM and 7:00 PM. Tag numbers of previously captured fish were recorded along with their current spawning condition. Fish were released on the downstream side of the counting fence into the channel.

As a check on tagging and handling stress, several fish were placed into a retaining pen after initial examination and tagging at the upstream trap. Fish were reexamined and released to the pool after 24 hours.

The 1989 season was the first year of operation of the Siisiip Marsh Complex by Ducks Unlimited. The marsh complex did not fill in 1989 due to low runoff therefore there was insufficient head to properly operate the fishways. The steeppass fishway was non-functional throughout the 1989 field season whereas the standard Denil fishway could be operated only at depths of six to eight centimetres.

The main objectives of the study could not be addressed in 1989 due to the low water levels. However, several pike were placed in resting pools in the standard Denil fishway to determine if they would ascend under these conditions and observations were made of their behaviour in the resting pools (Appendix 4).

5.2.5.2 1990, Experiment One

The counting fence could not be installed during the early stages of the 1990 study due to thick ice along the channel banks. Instead, gill nets were used to capture fish entering the study area. Use of small mesh nets along with frequent monitoring insured that injuries to pike were minimized.

All gillnetted fish were subjected to tagging and examination as described in Section 5.1.1 and released back into the channel. Six pike were held in the retaining pen for 24 hours as a check on handling stress, then released to the channel.

Fishway operation was divided into twenty, twelve hour periods corresponding roughly to day (7:00 AM to 7:00 PM) and night (7:00 PM to 7:00 AM) (Table 1). The fishways were operated at both low and high flow regimes. For each 48 hour period, the flow regime for the first day period was chosen by a coin toss and the flow regime for the second day period was determined by default. Flow regimes for each night period were determined in the same manner. This ensured that high and low flows were equally represented during days and nights throughout the study period.

Flows were controlled by addition or removal of bars in the exit traps to obtain the desired depth in the fishway channels. The low flow regime was indicated by a depth of about 25 cm and the high flow regime by a depth of about 40 cm. Both fishways were always operated with matching flow regimes. It should be noted that fishways are generally operated at greater depths than these. However, headwater elevations relative to the fishway limited the maximum depth

Table 1. Operating periods and flow levels in Siisiip Fishways during Experiment One, 1990.

Period	Time and Date	Day/Night	Flow Level
1	7 AM May 3 to 7 PM May 3	Day	High
2	7 PM May 3 to 7 AM May 4	Night	High
3	7 AM May 4 to 7 PM May 4	Day	Low
4	7 PM May 4 to 7 AM May 5	Night	Low
5	7 AM May 5 to 7 PM May 5	Day	High
6	7 PM May 5 to 7 AM May 6	Night	High
7	7 AM May 6 to 7 PM May 6	Day	Low
8	7 PM May 6 to 7 AM May 7	Night	Low
9	7 AM May 7 to 7 PM May 7	Day	High
10	7 PM May 7 to 7 AM May 8	Night	Low
11	7 AM May 8 to 7 PM May 8	Day	Low
12	7 PM May 8 to 7 AM May 9	Night	High
13	7 AM May 9 to 7 PM May 9	Day	High
14	7 PM May 9 to 7 AM May 10	Night	High
15	7 AM May 10 to 7 PM May 10	Day	Low
16	7 PM May 10 to 7 AM May 11	Night	Low
17	7 AM May 11 to 7 PM May 11	Day	High
18	7 PM May 11 to 7 AM May 12	Night	High
19	7 AM May 12 to 7 PM May 12	Day	Low
20	7 PM May 12 to 7 AM May 13	Night	Low

Table 2. Operating periods and flow levels in Siisiip Fishways during Experiment Two, 1990.

Period	Time and Date	Day/Night	Flow Level
21	7 PM May 13 to 7 AM May 14	Night	Low
22	7 AM May 14 to 7 PM May 14	Day	High
23	7 PM May 14 to 7 AM May 15	Night	High
24	7 AM May 15 to 7 PM May 15	Day	Low
25	7 PM May 15 to 7 AM May 16	Night	Low
26	7 AM May 16 to 7 PM May 16	Day	Low
27	7 PM May 16 to 7 AM May 17	Night	High
28	7 AM May 17 to 7 PM May 17	Day	High
29	7 PM May 17 to 7 AM May 18	Night	Low
30	7 AM May 18 to 7 PM May 18	Day	High
31	7 PM May 18 to 7 AM May 19	Night	High
32	7 AM May 19 to 7 PM May 19	Day	Low

of flow in this study.

In Experiment One, dividers were kept in place in the resting pools at all times. Thus, if a fish entered either fishway at the entrance, it had to ascend that fishway to the exit, or turn around and leave the fishway completely. Throughout Experiment One tailwater levels remained high, such that flow was consistently fully developed only in the upper channel and the lower channels were consistently subjected to backwater effects. Fish were therefore unable to distinguish between fishways based on flow patterns at the entrances and entry to either fishway was determined by chance.

Since it can be assumed that approximately equal numbers of fish entered each fishway, a comparison of the number of fish ascending the fishways indicates the ability of the fish to ascend each fishway regardless of any preference they may have for either flow pattern. The fishways were operated at two flow regimes, allowing passage comparisons between fishways at each flow regime and comparisons between flow regimes for each fishway.

Efficiency estimates were made by comparing the number of tagged pike that ascended the fishways to the total number of tagged pike.

5.2.5.3 1990, Experiment Two

The counting fence was installed on May 12 and 13 with the same layout as in 1989. Experiment Two began May 13. All fish captured in the upstream and downstream traps were tagged and examined as in 1989. Fish captured in the upstream trap were released upstream to the pool whereas fish captured in the downstream trap were released downstream to the channel. Fish were not retained for assessment of handling and tagging stress at this point to avoid delays in fishway ascents. Instead, several pike that later ascended the fishways were held overnight in the retaining pen to check for handling stress.

Fishway operation was divided into twelve periods of twelve hours each with an even number of high and low flow regimes (Table 2). High and low flow regimes were determined in the same manner as in Experiment Two.

In Experiment Two, the dividers were removed from the resting pools below the lowermost fishway channels exhibiting fully developed flow. In most periods, this was the upper resting pool. However, in three periods fully developed flow was evident in the middle pair of channels. In those periods, the dividers were removed from the lower resting pool and dividers replaced in the upper resting pool. This ensured that fish were able to make a choice between fishways based on the flow pattern before they entered but that once they entered, they could not gain access to the other fishway. Since fish were able to choose which fishway to enter based on the flow pattern, Experiment

Two not only assessed their ability to ascend the fishway but also their preference for either fishway.

Fishways were operated at two flow regimes allowing comparisons to be made between fishways at each flow regime and between flow regimes for each fishway.

5.2.6 Swimming Speed of Northern Pike

The swimming speed of northern pike using the fishways was estimated by two means. In the first method, an orange bar was fastened in each fishway at the upper end of the upper channel, horizontally at a height of 20 cm from the bottom of the fishways. Ascending pike were then observed to swim either over or under the bar. Since both fishways had predictable water velocities at particular depths, the approximate water velocity against which the pike ascended could be determined (this assumes that the pike maintained approximately the same depth of ascent through the fishway and therefore encountered the same water velocities). This velocity represents the minimum swimming speed of the fish.

In the second method, pike were observed to enter the upper channel of the fishway and their ascent to the exit was timed. The sum of the water velocity in the fishway and the calculated forward velocity of the fish represented the swimming speed.

5.3 Data Analysis

5.3.1 Passage Comparisons

For both experiments, there were four combinations of fishways and flow regimes - standard Denil with low flow, standard Denil with high flow, steeppass with low flow and steeppass with high flow. A G-test was performed to determine if the observed frequencies of passage among these combinations differed from the expected frequencies. Pair-wise G-tests were then performed between fishways at each flow regime and between flow regimes for each fishway. It is not valid to perform a large number of pair-wise comparisons because some apparently significant differences will occur simply by chance. However, only four comparisons were made in each experiment, minimizing the possibility of a Type I error.

For G-tests involving two sample comparisons a continuity correction was applied (Sokal and Rohlf 1981, Prepas 1982). Where $n < 25$, exact probabilities were calculated (Sokal and Rohlf 1981).

5.3.2 Physical Characteristics of Fish

Comparisons of population features were made to determine if the fishways selected against any segment of the fish population. Comparisons were first made between fish ascending the standard Denil fishway and fish ascending the steeppass fishway. For each characteristic, if no differences were found, data for the two fishways were combined. The ascending fish were then compared to the non-ascending fish with respect to that feature.

Population features considered were length, sex and spawning condition. In comparing lengths, data were first tested for normality using the Kolmogorov-Smirnov test where $n < 30$ and the chi-square test for normality where $n > 30$ (Sokal and Rohlf 1981, Prepas 1982). Homogeneity of variances was confirmed and lengths were then compared using t-tests. G-tests were used to compare sex and spawning condition of ascending and nonascending fish.

Comparisons were not made for fish in Experiment One. As explained in subsequent sections, it is likely that some of the gillnetted fish in Experiment One were capable of ascending the fishways but did not, due to the effects of handling stress. Inclusion of these fish with nonascending fish would bias the results, therefore comparisons were made for Experiment Two only.

5.3.3 Efficiency Estimate

5.3.3.1 Definition

Fishway efficiency is defined as the number of fish that enter and successfully ascend a fishway, relative to the number of fish that are in the vicinity of the fishway and available for ascent. This definition allows for a complete assessment of fishway passage efficiency since it considers not only the suitability of conditions within the fishway but also the suitability of entrance conditions.

5.3.3.2 Tracking of Fish

To determine fishway efficiency, it was necessary to know how many fish were in the pool available for ascent. Further, to make comparisons of population characteristics between ascending and non-ascending fish, it was necessary to know which individual fish were available in the pool.

Fish were tracked through the study area during Experiment Two by recording tag numbers at all entrances and exits in the area. Tag numbers were recorded as fish were released to the pool from the upstream trap and when the fish leaving the area were captured in the downstream trap and the fishway traps. Fish were added to the pool daily at about 7:00 AM from the upstream trap. Fish were recorded leaving the pool via the downstream trap and the fishways twice daily at 7:00 AM and 7:00 PM. It was therefore possible to monitor the numbers and identity of individual fish in the pool for each twelve hour period of the study.

5.3.3.3 Aggregate Efficiency

Aggregate efficiency is the total number of fish that ascended both fishways at both flow rates, relative to the number of fish available for ascent.

In Experiment One, the fish available for ascent consisted of all fish caught in the pool area by gill net and tagged whereas ascents were any of these tagged fish that ascended the fishways. Two estimates of aggregate efficiency were made in Experiment Two. The first estimate considered only fish that entered from the upstream trap and were tracked through the study area to one of the exit points or were gill netted from the pool at the end of the study. This represents a maximum estimate of efficiency. However, several fish were not accounted for in this manner and may have escaped through a hole in the centre lead of the counting fence. A second estimate of efficiency was made which included these fish as available for passage and represents the minimum passage efficiency.

5.3.3.4 Fishway/Flow Regime Efficiencies

For each of the four combinations of fishway types and flow regimes in Experiment Two, individual efficiencies were determined by the ratio of the number of ascending fish to the number of fish available for ascent. In each case, the number of fish ascents was obtained by summing the number of ascents of the applicable fishway in each of the twelve hour periods having the appropriate flow regime. The number of fish available for ascent was obtained by counting all fish that were present in the pool during at least one twelve hour period of the appropriate flow regime.

These efficiencies were not determined for Experiment

One due to the low number of ascents of tagged fish.

5.3.3.5 Period Efficiencies

The period efficiency is the number of pike ascending during a twelve hour period relative to the number available for ascent during the same period. Period efficiencies were calculated for each of the twelve periods in Experiment Two, in aggregate and for each fishway. Mean period efficiencies were also calculated for all four fishway/flow combinations.

6. Results

6.1 Physical Conditions

6.1.1 Water Temperatures

6.1.1.1 1989

Water temperatures for the Centre Angling River and the fishways are shown in Table 3. Gaps in the fishway temperature data are due to absences from the site. Water temperatures at the fishway were consistently warmer than the river due to early breakup and warming of the shallow Dumbell-Knudsen Marsh.

6.1.1.2 1990

Water temperatures in 1990 were generally colder than in 1989 due to unusually cold weather lasting until mid-May (Table 4). As in 1989, water temperatures at the fishway were warmer than the river due to the shallow, rapidly

Table 3. Water temperatures in Centre Angling River and Siisiip fishways, 1989.

	Water Temperature (°C)		
Date	River (Afternoon)	Fishway (AM)	Fishway (PM)
April 25			8.5
26		6.0	11.0
27	3.0	1.0	10.0
28		7.0	9.5
29			
30			
May 1			
2		8.5	10.0
3		7.0	8.5
4		7.0	8.0
5		6.0	8.5
6	5.0	7.5	10.5
7	6.0	8.0	11.0
8		8.0	11.0
9	6.0	9.0	
10		12.5	12.0
11	7.0	13.0	12.0
12	8.0	14.0	18.0
13	9.0	15.5	18.0
14		13.0	20.0
15	8.5	14.0	12.0
16	7.0	13.0	15.0

Table 4. Water temperatures in Centre Angling River and Siisiip fishways, 1990.

Date		Water Temperature (°C)		
		River (Afternoon)	Fishway (AM)	Fishway (PM)
May	2		3.5	5.0
	3		4.0	5.0
	4		4.0	5.0
	5	3.0	4.0	5.5
	6	2.5	4.5	7.0
	7	3.5	4.5	3.0
	8		3.0	5.0
	9	4.5	4.5	6.0
	10	5.0	6.0	7.0
	11		6.0	7.0
	12	2.5	7.0	9.0
	13	3.5	7.5	10.0
	14	3.5	9.5	11.5
	15		9.0	11.0
	16		9.0	11.0
	17		9.0	12.0
	18			12.5

warming marsh above the fishways.

6.1.2 Headwater and Tailwater Elevations

6.1.2.1 1989

Headwater and tailwater elevations are listed in Table 5. Dumbell-Knudsen Marsh fills by local runoff and by flow diverted from the Centre Angling River. Unusually low snowfall in the winter of 1988-89 resulted in low runoff and headwater levels did not rise during the study period. The maximum headwater elevation reached was 268.87 metres ASL on April 28 but this declined to 268.57 metres ASL by the end of the study. This was only slightly above the invert elevation of 268.53 metres ASL for the fishway exit and considerably less than the full supply level for the marsh of 269.14 metres ASL.

Diel tailwater elevations fluctuated considerably due to the operation of the E. B. Campbell Dam Hydro Station, located 70 kilometres upstream. Tailwater elevations regularly rose during the daytime and dropped overnight. The average fluctuation over a twelve hour period was .26 metres with the maximum difference of .68 metres occurring on May 9.

Tailwater fluctuations resulted in considerable variations in head. Head varied from .72 metres to 2.02 metres with a mean of 1.3 metres (Table 5).

Table 5. Geodetic headwater and tailwater elevations at Siisiip fishways, 1989.

		Elevation (m ASL)		
Date	Time	Headwater	Tailwater	Head (m)
April 25	500 PM	268.33	267.48	.85
26	1145 AM	268.51	267.79	.72
26	700 PM	268.57	267.71	.86
27	700 AM	268.66	267.84	.82
27	345 PM	268.69	267.77	.92
28	845 AM	268.87	267.84	1.03
28				
29				
29				
30				
30				
May 1				
1				
2	1030 AM	268.82	267.50	1.32
2	510 PM	268.75	267.16	1.59
3	700 AM	268.75	267.43	1.32
3	700 PM	268.75	266.98	1.77
4	715 AM	268.69	267.31	1.38
4	445 PM	268.64	267.23	1.41
5	700 AM	268.64	267.31	1.33
5	700 PM	268.64	267.07	1.57
6	745 AM	268.75	267.42	1.33
6	415 PM	268.57	267.05	1.52
7	700 AM	268.39	267.19	1.20
7	800 PM	268.39	266.72	1.67
8	715 AM	268.39	266.88	1.51
8	745 PM	268.33	266.80	1.53
9	700 AM	268.37	267.48	.89
9				
10	730 AM	268.46	267.63	.83
10	700 PM	268.55	267.28	1.27
11	650 AM	268.51	267.57	.94
11	700 PM	268.57	267.18	1.39
12	730 AM	269.49	267.47	2.02
12	650 PM	268.57	267.16	1.41
13	735 AM	268.57	267.46	1.11
13	710 PM	268.56	267.04	1.52
14	700 AM	268.56	267.15	1.41
14	700 PM	268.57	266.98	1.59
15	715 AM	268.56	267.08	1.48
15	700 PM	268.56	267.04	1.52
16	700 AM	268.56	267.49	1.07
16	700 PM	268.57	266.94	1.63

6.1.2.2 1990

Headwater and tailwater elevations for 1990 are listed in Table 6. Water levels in Dumbell-Knudsen Marsh approached the full supply level in 1990. The maximum headwater elevation was 269.08 metres ASL on May 19, just .06 metres below full supply level.

Tailwater levels varied less than in 1989, with a mean difference over twelve hours of .15 metres and a maximum twelve hour difference of .51 metres. Head varied from .84 metres to 1.71 metres with a mean of 1.16 metres.

6.1.3 Fishway Water Velocities

Low headwater elevations in 1989 prevented proper operation of the fishways. The steeppass fishway was nonfunctional throughout the study period and only a minimal depth of flow occurred in the standard Denil fishway. Maximum depth of flow was about .08 metres and water velocity was estimated at about .35 m/sec.

6.1.3.1 1990

Both fishways were fully operational throughout the 1990 study period. Tables 7 and 8 contain depth, discharge and velocity data for the standard Denil fishway at low and high flow, respectively, while Tables 9 and 10 contain these data for the steeppass fishway at low and high flow. Average values for each fishway at each flow rate are

Table 6. Geodetic headwater and tailwater elevations at Siisiip fishways, 1990.

		Elevation (m ASL)		
Date	Time	Headwater	Tailwater	Head (m)
April 27	700 PM	268.93		
28	700 PM	268.93		
29	700 AM	268.96		
29	700 PM	268.96	267.85	1.11
30	1100 AM	268.96	267.58	1.38
30	700 PM	268.96	267.49	1.47
May 1	800 AM	268.96	267.79	1.17
1	700 PM	268.96	267.57	1.39
2	715 AM	268.96	267.96	.99
2	715 PM	268.96	267.99	.97
3	700 AM	268.96	268.07	.90
3	700 PM	268.97	268.12	.85
4	700 AM	268.98	268.08	.90
4	715 PM	268.98	267.87	1.12
5	700 AM	268.99	267.95	1.03
5	700 PM	268.99	267.93	1.06
6	700 AM	268.99	267.89	1.11
6	720 PM	268.99	267.73	1.26
7	700 AM	268.99	267.53	1.46
7	700 PM	268.99	267.28	1.71
8	715 AM	269.00	267.94	1.06
8	700 PM	269.01	267.96	1.05
9	710 AM	269.02	268.12	.90
9	700 PM	269.02	268.12	.90
10	700 AM	269.03	268.19	.85
10	700 PM	269.03	268.14	.90
11	700 AM	269.05	268.20	.84
11	700 PM	269.05	268.21	.84
12	700 AM	269.06	268.21	.85
12	645 PM	269.06	268.06	1.00
13	700 AM	269.06	267.95	1.11
13	710 PM	269.07	267.74	1.32
14	700 AM	269.07	267.64	1.42
14	700 PM	269.05	267.49	1.57
15	700 AM	269.07	267.64	1.43
15	700 PM	269.06	267.19	1.87
16	700 AM	269.05	267.57	1.48
16	645 PM	269.04	267.42	1.62
17	700 AM	269.05	267.93	1.12
17	645 PM	269.06	267.86	1.21
18	645 AM	269.07	267.89	1.18
18	720 PM	269.07	267.89	1.19
19	700 AM	269.07	268.10	.98
19	645 PM	269.08	268.14	.94

Table 7. Calculated discharge and velocity values for standard Denil fishway at low flow, 1990.

Slope = 1:10, b = .406 $Q = .098(yo/b)^2$

Period	Water Depth d (m)	Discharge Q (cu m / s)	Local depth y (m) (vertical distance above the baffle "V") .05	.10	.15	.20	.25	Average Velocity U (m / s)
			Local velocity u (m/s), at the above local depth					
3	.257	.039	.158	.160	.191	.285	.474	.254
4	.248	.037	.151	.154	.189	.293		
7	.268	.043	.166	.167	.194	.278	.488	.251
8	.279	.046	.175	.175	.198	.273	.427	.250
10	.219	.029	.130	.136	.189	.333		
11	.251	.037	.153	.156	.190	.290	.491	.256
15	.264	.041	.163	.164	.193	.280	.457	.251
16	.257	.039	.158	.160	.191	.285	.474	.254
19	.285	.048	.179	.179	.201	.271	.417	.252
20	.283	.048	.178	.178	.200	.271	.420	.249
21	.235	.033	.141	.146	.188	.308		
24	.252	.038	.154	.156	.190	.289	.488	.255
25	.240	.034	.145	.149	.188	.301		
26	.259	.040	.159	.161	.192	.284	.469	.253
29	.268	.043	.166	.167	.194	.278	.448	.251
32	.263	.041	.163	.164	.193	.281	.460	.252
Low Flow Means	.258	.040	.159	.161	.193	.288	.459	.252

Table 8. Calculated discharge and velocity values for standard Denil fishway at high flow, 1990.

Slope = 1:10, b = .406 $Q = .098(yo/b)^2$

			Local depth y (m) (vertical distance above the baffle "V")								
	Water Depth	Discharge Q	.05	.10	.15	.20	.25	.30	.35	.40	Average Velocity
Period	d (m)	(cu m / s)	Local velocity u (m/s), at the above local depth								U (m / s)
1	.373	.083	.200	.207	.215	.250	.336	.501	.771		
2	.380	.086	.204	.212	.219	.251	.333	.490	.746		
5	.406	.098	.220	.229	.235	.260	.325	.454	.669	.992	.423
6	.383	.087	.206	.214	.221	.252	.332	.485	.736		
9	.382	.087	.205	.213	.221	.252	.332	.486	.739		
12	.434	.112	.237	.248	.253	.271	.323	.429	.607	.879	.406
13	.408	.099	.221	.231	.236	.260	.325	.452	.664	.983	.422
14	.411	.100	.223	.233	.238	.261	.324	.449	.657	.970	.419
17	.403	.097	.218	.227	.233	.258	.326	.458	.677	1.006	.425
18	.403	.097	.218	.227	.233	.258	.326	.458	.677	1.006	.425
22	.415	.102	.226	.235	.241	.263	.324	.445	.647	.952	.417
23	.389	.090	.210	.218	.225	.254	.329	.476	.717		
27	.419	.104	.228	.238	.243	.265	.324	.441	.638	.936	.414
28	.407	.098	.221	.230	.236	.260	.325	.453	.666	.988	.422
30	.408	.099	.221	.231	.236	.260	.325	.452	.664	.983	.422
31	.393	.092	.212	.231	.227	.255	.328	.470	.705		
High Flow Means	.401	.096	.217	.226	.232	.258	.327	.462	.686	.970	.422

Table 9. Calculated discharge and velocity values for steeppass fishway at low flow, 1990.

Slope = 1:10, b = .406   Q = .101(yo/b)^1.55

Period	Water Depth d (m)	Discharge Q (cu m / s)	Local depth y (m) (vertical distance above the baffle "V") .05	.10	.15	.20	.25	Average Velocity U (m / s)
			Local velocity u (m/s), at the above local depth					
3	.251	.048	.456	.314	.216	.149		
4	.236	.044	.426	.286	.192	.129	.102	.247
7	.254	.049	.463	.320	.221	.153		
8	.248	.047	.450	.308	.211	.145	.105	.252
10	.208	.036	.367	.234	.149	.095		
11	.245	.046	.444	.303	.206	.141		
15	.318	.069	.589	.438	.326	.243		
16	.259	.050	.473	.329	.229	.159	.181	.355
19	.293	.061	.540	.392	.285	.207	.111	.260
20	.295	.062	.544	.396	.288	.209	.150	.315
21	.231	.042	.415	.277	.184	.123	.152	.318
24	.243	.046	.440	.299	.203	.138		
25	.219	.039	.390	.254	.166	.108		
26	.270	.054	.495	.349	.247	.174		
29	.225	.040	.403	.265	.175	.115	.123	.277
32	.269	.053	.493	.348	.245	.173	.122	.276
Low Flow Means	.254	.049	.462	.320	.221	.154	.131	.258

Table 10. Calculated discharge and velocity values for steeppass fishway at high flow, 1990.

Slope = 1:10, b = .406   Q=.101(yo/b)^1.55

			Local depth y (m) (vertical distance above the baffle "V")								
	Water Depth	Discharge Q	.05	.10	.15	.20	.25	.30	.35	.40	Average Velocity
Period	d (m)	(cu m / s)	Local velocity u (m/s), at the above local depth								U (m / s)
1	.370	.087	.687	.533	.414	.321	.249	.193	.150		
2	.383	.092	.711	.556	.435	.341	.267	.209	.163		
5	.391	.095	.726	.571	.449	.353	.278	.218	.172		
6	.388	.094	.720	.565	.444	.348	.274	.215	.169		
9	.379	.091	.704	.549	.429	.335	.261	.204	.159		
12	.420	.106	.778	.622	.498	.398	.318	.254	.203		
13	.410	.103	.760	.605	.481	.382	.304	.242	.192	.153	.390
14	.424	.108	.785	.629	.504	.404	.324	.260	.208	.167	.410
17	.414	.104	.767	.612	.488	.389	.310	.247	.197	.157	.396
18	.421	.107	.780	.624	.499	.399	.320	.256	.205	.164	.406
22	.444	.116	.821	.664	.538	.435	.352	.285	.231	.187	.439
23	.428	.110	.793	.636	.511	.410	.330	.265	.212	.171	.416
27	.433	.112	.801	.645	.519	.418	.337	.271	.218	.176	.423
28	.422	.107	.782	.626	.501	.401	.321	.257	.206	.165	.407
30	.436	.113	.807	.650	.524	.423	.341	.275	.222	.179	.428
31	.429	.110	.794	.638	.513	.412	.331	.266	.214	.172	.418
High Flow Means	.412	.103	.764	.608	.484	.386	.307	.245	.195	.169	.395

summarized in Table 11.

The two fishways had comparable discharges and mean velocities for the low flow regime. For the high flow regime, discharges were similar but mean velocities (U) varied slightly. At high flows, the standard Denil fishway had a slightly higher mean velocity of .422 m/sec compared to the steeppass fishway at .395 m/sec.

Velocity profiles for each fishway/flow regime are depicted in Figure 9.

6.2 Arrival of Northern Pike

6.2.1 Arrival Dates

Dates of arrival of northern pike at the fishways in 1989 are shown in Table 12. Monitoring of arrivals did not begin until May 4 when the counting fence was installed.

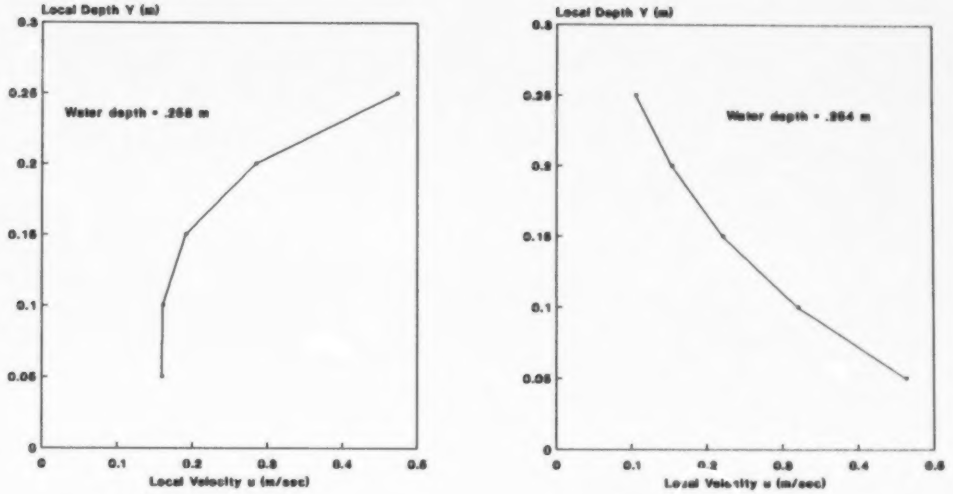
Arrival dates for pike in 1990 are shown in Table 13. Initially, arrival dates were monitored by captures in the fishway traps and by gill net captures in the channel. Beginning May 13, arrivals were monitored at the upstream trap of the counting fence and to a lesser extent, at the fishway cages.

6.2.2 Relation of Pike Arrivals to Water Temperatures

Figure 10 compares arrival dates of northern pike in 1989 to water temperatures in the Centre Angling River and the channel downstream of the fishways. The same comparison

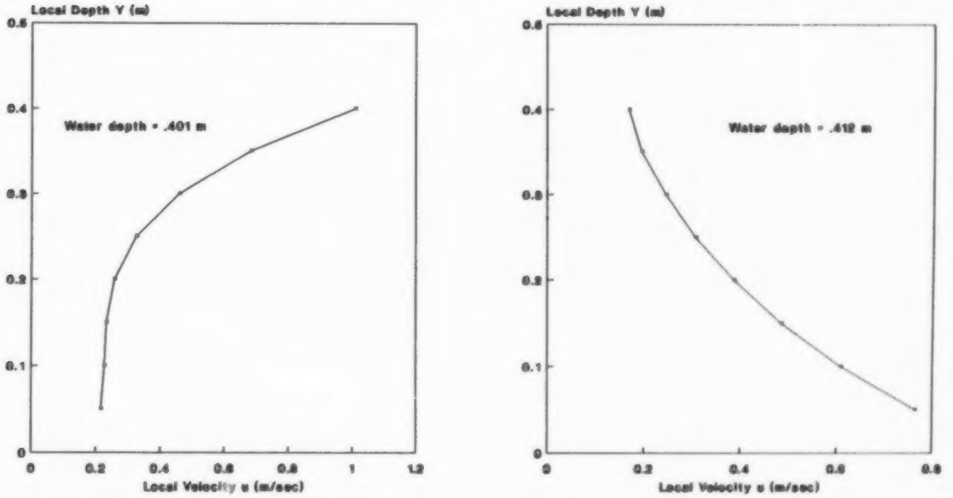
Table 11. Summary of mean depth, mean discharge, depth-averaged velocities and local velocities for standard Denil and steeppass fishways at low and high flow regimes.

Fishway/Flow	Mean Depth Yo (m)	Discharge Q (cu m/sec)	Average Velocity U (m/sec)	Local Depth Y (m)							
				.05	.10	.15	.20	.25	.30	.35	.40
				Local Velocity u (m/sec)							
Standard/Low	.258	.040	.252	.159	.161	.193	.288	.459			
Steeppass/Low	.254	.049	.258	.462	.320	.221	.154	.131			
Standard/High	.401	.096	.422	.217	.226	.232	.258	.327	.462	.686	.970
Steeppass/High	.412	.103	.395	.764	.608	.484	.386	.307	.245	.195	.169



Standard Denil fishway at low flow

Steeppass fishway at low flow



Standard Denil fishway at high flow

Steeppass fishway at high flow

Figure 9. Depth velocity profiles for each fishway/flow combination in 1990.

Table 12. Dates of arrival of northern pike at Siisiip fishways, 1989.

Date		Arrivals
May	4	14
	5	40
	6	Not Lifted
	7	28
	8	2
	9	3
	10	6
	11	12
	12	11
	13	1
	14	1
	15	2
	16	1

Note: Trap installation and monitoring began on May 4.

Table 13. Dates of arrival of northern pike at Siisiip fishways, 1990.

	Capture Location			
Date	Gill Net	Upstream Trap	Fishway Trap	Combined
May 2			1	1
3				0
4			1	1
5	2		12	14
6	8		10	18
7	6		12	18
8	11		3	14
9	5		5	10
10	2		5	7
11	2		4	6
12	6		3	9
13	1	3	2	6
14		7		7
15		19	1	20
16		5	4	9
17		12	4	16
18		9	2	11
19		1		1

Note: Fishway cages operated from May 2 to May 19. Upstream traps operated May 13 to May 19. Gill nets used from May 5 to May 13; gill net effort not equal each day.

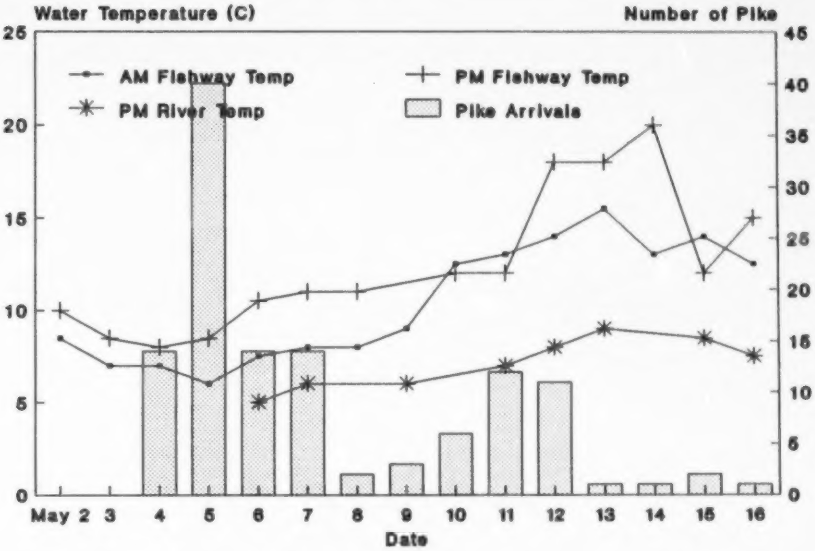


Figure 10. Comparison of arrival dates of northern pike to water temperature in fishways and Centre Angling River, 1989

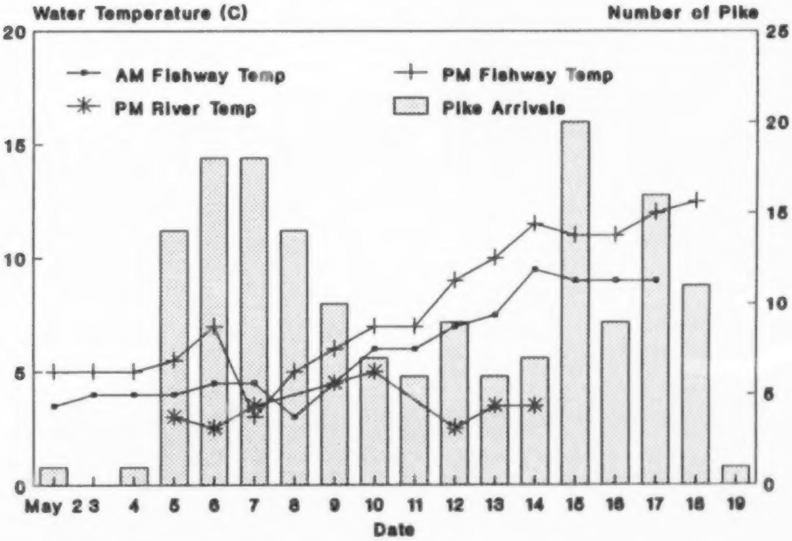


Figure 11. Comparison of arrival dates of northern pike to water temperature in fishways and Centre Angling River, 1990

is made in Figure 11 for 1990. In both years, there is no apparent relationship between pike arrivals at the fishways and water temperatures either in the river or in the channel. In both years, water temperatures in the river and the channel generally rose through the study. However, most pike arrived in two periods in the early and later portions of the study at considerably different water temperatures.

6.2.3 Relation of Pike Arrivals to Tailwater Elevations

Tailwater elevations and arrival dates of northern pike are compared in Figure 12 for 1989 and in Figure 13 for 1990. In both years, there appeared to be a relation between changing tailwater elevations and the frequency of arriving pike. This relationship was most pronounced in 1990. Large scale arrivals of pike beginning May 5 coincided with a sharp drop in tailwater levels while declining pike arrivals after May 7 coincided with rising tailwater elevations. Another increase in pike arrivals on May 15 corresponded to declining water levels.

This relationship may be explained by local flow patterns in the area. Tailwater elevations are controlled by water levels in the Centre Angling River. As levels in the river rise, water flows up the channel, raising the water level at the fishways. As the river drops, water flows from the fishways towards the river. Thus, rising tailwater elevations at the fishways indicate reverse flow

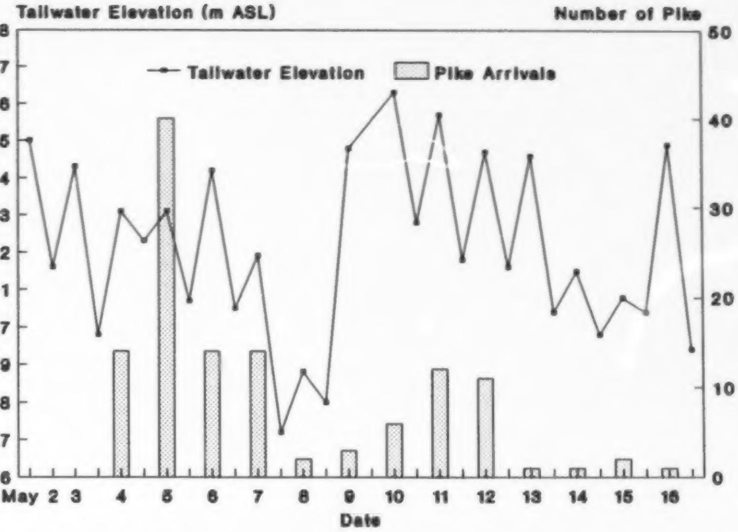


Figure 12. Comparison of arrival dates of northern pike to tailwater elevations below fishways, 1989.

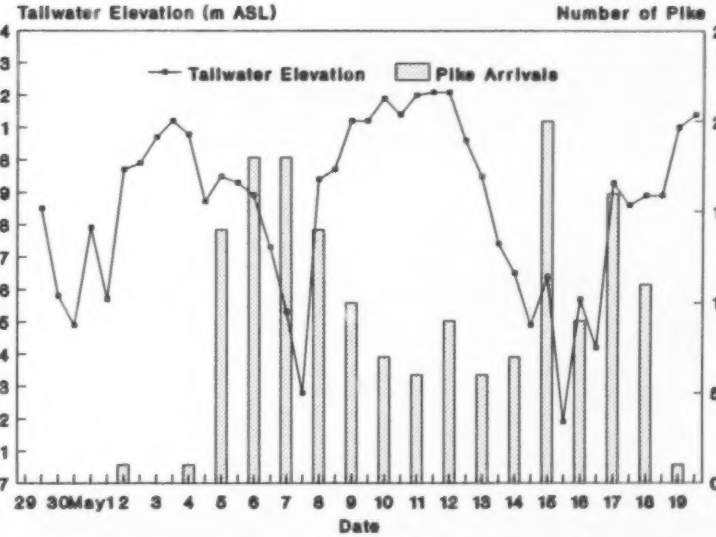


Figure 13. Comparison of arrival dates of northern pike to tailwater elevations below fishways, 1990.

in the channel and declining tailwaters indicate a return to the normal direction of flow, away from the fishways to the river. Fish generally migrate upstream during spring spawning runs, ascending against the current (Harden-Jones 1968). Pike can therefore be expected to arrive at the fishways when tailwater elevations are declining as this occurs during the normal flow pattern. When tailwater elevations are rising, the current is flowing from the river and pike may be expected to migrate in that direction, reducing the frequency of arrivals at the fishways.

Pike spawning migrations may be initially triggered by rising water temperatures but local water level fluctuations probably also influence movements to the fishway from the Centre Angling River.

6.2.4. Physical Characteristics of Pike Arriving at the Fishways

6.2.4.1 Length

Length frequency distributions for pike arriving at the fishways in 1989 and 1990 are shown in Figures 14 and 15. The mean fork length for northern pike was 57.0 cm in 1989 and 51.5 cm in 1990.

The length - weight relationship for northern pike in 1989 was $W = .008705676\ L^{2.97005619}$. In 1990, the length - weight relationship was $W = .005808936\ L^{3.0304615}$.

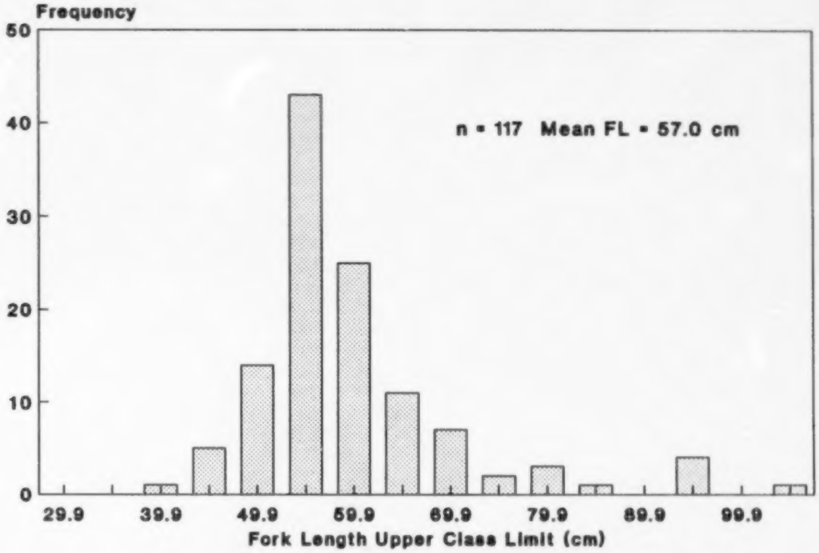


Figure 14. Length frequency distribution of pike arriving at Siisiip fishways in 1989.

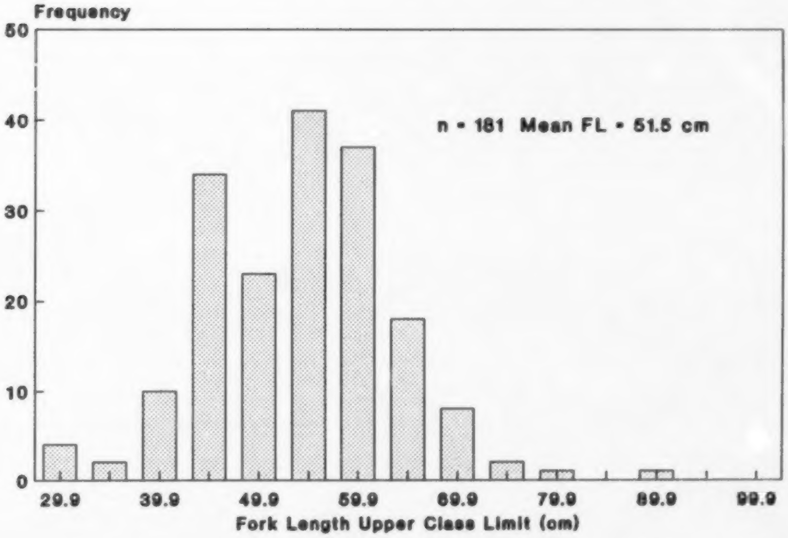


Figure 15. Length frequency distribution of pike arriving at Siisiip fishways in 1990.

6.2.4.2 Sex

Males predominated in the spawning runs in 1989 and 1990 but the sex ratio differed considerably (Tables 14 and 15). The sex ratio was about 2.1 males per female in 1989 and 5.5 males per female in 1990.

6.2.4.3 Spawning Condition

The spawning condition of pike arriving at the fishways in 1989 and 1990 is shown in Tables 16 and 17. In both years, about one-tenth of the pike arrived green. On average, pike were in a later stage of spawning condition in 1990 than in 1989. The greater number of spent pike in 1990 may be explained by generally higher tailwater elevations (267.30 m ASL in 1989 and 267.86 m ASL in 1990). Considerable areas of meadows between the fishways and the river were flooded and available as spawning areas in 1990 but were not accessible to pike in 1989.

6.2.5 Arrival and Physical Characteristics of White Suckers

Seven white suckers were captured in the fishway vicinity in 1989. All were similar in size, averaging 44.7 cm fork length. All but two had spawned before their arrival. White sucker arrivals occurred sporadically between May 5 and May 16 with no apparent relationship to water temperatures or tailwater elevations. Details are contained in Appendix 5.

Table 14. Sex of northern pike arriving at Siisiip fishways, 1989.

Arrival Date	Sex	
	Male	Female
May 4	7	7
5	25	10
6	Trap not emptied	
7	19	8
8	1	1
9	2	1
10	5	2
11	9	2
12	5	3
13	1	
14		1
15		1
Total	74	36

Sex ratio - 2.06:1

Table 15. Sex of northern pike arriving at Siisiip fishways, 1990.

Arrival Date	Sex	
	Male	Female
May 5	2	
6	5	1
7	7	1
8	8	
9	2	2
10	2	
11	1	
12	2	1
13	3	
14	4	1
15	10	5
16	6	
17	9	
18	4	1
19	1	
Total	0	0

Sex ratio 5.5:1

Note: Only fish that were initially captured in the upstream trap or in gill nets below the fishways are included. Fish that were initially captured in the fishway exit traps are not included in case of sex selection by the fishways.

Table 16. Spawning condition of northern pike arriving at Siisiip fishways, 1989.

Condition	Number	Per Cent
Green	12	10.0
Expressing	74	61.7
Ripe	17	14.2
Spent	17	14.2

Table 17. Spawning condition of northern pike arriving at Siisiip fishways, 1990.

Condition	Number	Per Cent
Green	18	11.8
Expressing	55	40.0
Ripe	40	26.1
Spent	40	26.1

Fifty-three white suckers were captured below the fishways in 1990 (Appendix 6). Most arrived on May 17 with a few arriving on May 18. Most white suckers left the area on May 18 and later. Arrival of white suckers on May 17 corresponded to a period of increasing tailwater elevations while departures occurred as tailwater elevations stabilized.

All white suckers were similar in size with a mean fork length of 47.0 cm. Eighty-two per cent of white suckers were female and 96% had spawned before their arrival at the fishways. These fish may have been returning down the Centre Angling River from a spawning migration and were diverted into the fishway access channel by the reversed direction of flow on May 17.

6.2.6 Tagging of Arriving Fish

6.2.6.1 1989

Northern pike tagged in 1989 are listed chronologically in Appendix 7 along with data on length, weight, sex, spawning condition, capture location, release location and date and time of capture. The same data are arranged by tag number in Appendix 8. A total of 121 northern pike were tagged in 1989. Seven white suckers and one shorthead redhorse sucker (*Moxostoma macrolepidotum* Lesueur) were also tagged in 1989 (Appendix 5).

Stress due to handling and tagging was assessed by holding eight pike in the retaining pen for 24 hours and observing their condition. All fish appeared to be in excellent condition when placed in the pen and when released. It is unlikely that handling and tagging resulted in any mortalities.

6.2.6.2 1990

A total of 172 northern pike were tagged in 1990. Tag numbers and pertinent data are listed chronologically in Appendix 9. Data are arranged by tag number in Appendix 10.

Fifty-three white suckers were tagged in 1990 (Appendix 6). In addition, two walleye, one yellow perch (*Perca flavescens* Mitchill), one burbot (*Lota lota* Linnaeus) and one shorthead redhorse sucker were captured and tagged (Appendix 11).

Handling stress was assessed as in 1989. Seven pike captured in the fishway exit traps and two white suckers captured in the upstream trap along with five pike captured in gill nets were held in the retaining pen for approximately 24 hours. All fish appeared to be in excellent condition when released.

During Experiment Two in 1990, twelve northern pike were tagged and released to the pool but not recaptured later at any of the exit points. Conversely, twenty-two untagged pike were captured at the exit points during Experiment Two. About half of these captures occurred in the first few days after installation of the fence and may have been fish that were already present in the area. During the last two days of the study, captures of untagged fish at the exit points increased. When the counting fence was removed at the end of the study, a ten centimetre diameter hole was found in the centre lead. This may explain both the disappearance of tagged pike from the pool and the entry of untagged pike to the pool.

6.3 Fish Passage in 1989

Due to low headwater elevations in 1989, the steeppass fishway was nonfunctional and the standard Denil fishway operated with a water depth of only about eight centimetres. In addition, an elevation difference of several centimetres where the upper fishway channel discharged into the upper resting pool made upstream passage by fish more difficult. Low flow through the fishways resulted in almost undetectable attraction flow at the fishway entrances.

No fish entered and ascended the fishways in 1989. However, several pike entered the standard Denil fishway and were able to ascend as far as the upper resting pool due to high water levels in the middle channel resulting from backwater effects. The existence of a small waterfall where the upper channel flow entered the resting pool prevented further ascent.

Manipulation of the water level in the resting pool to eliminate the waterfall made continued ascent to the fishway exit possible. Three groups of pike were then placed in the upper resting pool and their movements observed. Of thirteen pike, seven ascended from the upper resting pool to the exit.

Further modifications to baffle heights moderated differences in water elevation between pools and channels to allow continuous passage from entrance to exit in the standard Denil fishway. Of ten pike placed in the lower resting pool, eight ascended to the upper resting pool and seven of these continued to the fishway exit.

6.4 Experiment One, 1990

6.4.1 Fish Passage Comparisons

Fifty-seven pike ascended the fishways during Experiment One. Ascents by fishway and flow regime are shown in Table 18. A G-test indicated that the number of ascents among the four fishway and flow combinations were nonrandom ($G = 11.224$, $P < .025$).

6.4.2 Comparisons Between Fishways

During low flow periods, a total of sixteen pike ascended the standard Denil fishway and six ascended the steeppass fishway (Table 18). A G-test indicated that this difference was not significant ($G = 3.792$, $P > .05$).

During high flow periods, twelve pike ascended the

Table 18. Fishway ascents by northern pike during Experiment One, 1990.

	Ascents		
Flow	Steeppass	Standard	Total
Low	6	16	22
High	23	12	35
Total	29	28	57

$G = 11.224$

Critical value of $X^2 = 7.815$ at $P = .05$, $df = 3$
9.348 at $P = .025$ $df = 3$

Results are significant at $P = .025$

Pair-wise Comparisons	G	Significance
Steeppass fishway, low vs high flow	9.341	**
Standard Denil fishway, low vs high flow	.644	NS
Low flow, steeppass vs standard Denil	3.792	NS
High flow, steeppass vs standard Denil	2.897	NS

Critical value of $X^2 = 3.841$ at $P = .05$, $df = 1$
6.635 at $P = .01$, $df = 1$

standard Denil fishway and 23 pike ascended the steeppass fishway (Table 18). A G-test indicated that this difference was not significant (G = 2.897, P > .05).

6.4.3 Comparisons Between Flows

Considering only the standard Denil fishway, sixteen pike ascended during low flow periods and twelve ascended during high flow periods (Table 18). A G-test indicated that this difference was not significant (G = .644, P >.1).

For the steeppass fishway, six pike ascended during low flow periods while 23 ascended during high flow periods (Table 18). A G-test indicated that this difference was significant (G = 9.341, P < .005).

6.4.4 Efficiency

Forty-three tagged northern pike were available to ascend the fishways during Experiment One (Table 19). Only two ascended for an efficiency of 4.7%. Both fish ascended the steeppass fishway.

6.5 Experiment Two, 1990

6.5.1 Fish Passage Comparisons

Thirty northern pike ascended the fishways during Experiment Two. A G-test indicated that pike passage was random when all four combinations of fishways and flow conditions were considered together (G = 5.848, P > .1).

Table 19. Fishway efficiency estimated by passage of tagged pike captured in gill nets below the fishways during Experiment One, 1990.

Tagged pike available for ascent:

1166 *
1198
1199
1200
1401
1404
1405
1407
1408
7007
7010(7031)
7011
7015
7027
7028
7030
7034
7035
7036
7037
7038
7039
7040
7043
7049
7051
7053 *
7054
7055
7062
7063
7064
7065
7066
7078
7079
7082
7084
7085
7086
7087
7091
7092

* Ascended steeppass fishway

Available for ascent - 43
Ascents - 2

6.5.2 Comparisons Between Fishways

During low flow periods, eight pike ascended the standard Denil fishway and seven ascended the steeppass fishway (Table 20). This difference was not significant.

Three pike ascended the standard Denil fishway during high flow periods while twelve pike ascended the steeppass fishway (Table 20). The probability of these results occurring by chance alone was calculated at .034, therefore, results are significant at P = .05.

6.5.3 Comparison Between Flows

Eight pike ascended the standard Denil fishway during periods of low flow while three ascended during periods of high flow (Table 20). The probability of this difference occurring by chance alone was calculated at .227, therefore, the difference is not significant at P = .05.

For the steeppass fishway, seven pike ascended at low flow and twelve ascended at high flow (Table 20). The probability of these passage results occurring by chance alone was calculated at .360, therefore this difference is not significant at P = .05.

6.5.4 Efficiency Estimates

6.5.4.1 Aggregate Efficiency

Forty-nine tagged pike were tracked through the study area from entry to exit and were available to ascend the

Table 20. Fishway ascents by northern pike during Experiment Two, 1990.

	Ascents		
Flow	Steeppass	Standard	Total
Low	7	8	15
High	12	3	15
Total	19	11	30

$G = 5.848$

Critical value of $X^2 = 7.815$ at $P = .05$, $df = 3$

Results are not significant at $P = .05$

Pair-wise Comparisons	P	Significance
Steeppass fishway, low vs high flow	.36	NS
Standard Denil fishway, low vs high flow	.227	NS
Low flow, steeppass vs standard Denil	1	NS
High flow, steeppass vs standard Denil	.034	*

fishways (Table 21). Nineteen pike ascended for a maximum estimate of aggregate efficiency of 38.7%.

In addition to the pike that were tracked through the study area, thirteen pike were known to have entered the area but were not recaptured later. If these pike are considered to be available for ascent, the aggregate efficiency is estimated at 30.7% (Table 22). However, there were also eleven untagged pike that ascended the fishways during Experiment Two. This suggests that the undetected exit of tagged pike from the pool was balanced by the undetected entry of untagged pike to the pool. The actual efficiency is therefore close to the maximum estimate of 38.7%.

6.5.4.2 Fishway/Flow Regime Efficiencies

Tagged pike available for fishway ascent during low flow periods are listed in Table 23. Of 34 pike available, six ascended the standard Denil fishway and three ascended the steeppass fishway. During high flow periods, 28 pike were available for ascent (Table 24). One ascended the standard Denil fishway while ten ascended the steeppass fishway.

Passage efficiencies for each fishway and flow combination are as follows:

Standard Denil, low flow - 18%
Standard Denil, high flow - 4%

Table 21. Estimate of maximum aggregate fishway efficiency for northern pike, Experiment Two, 1990.

Tagged pike available for ascent (see note):

1414
1418
1420
7054
7095,7201 *
7099 **
7203 *
7205 *
7206 *
7208 *
7210 **
7214 **
7215
7216 **
7217 **
7218
7219
7220
7221 *
7222 *
7223
7224 *
7226
7227
7228
7229 **
7235
7236
7237
7238
7239 **
7245 *
7247 *
7248
7251
7252[1045] *
7253
7255
7258
7327
7332
7333 *
7334
7335
7337
7338
7352
7354
7365

* Ascended steeppass fishway
**Ascended standard Denil fishway

Steeppass ascents - 12
Standard Denil ascents - 7
Total ascents - 19
Number available for ascent - 49

Steeppass efficiency - 24.5%
Standard Denil efficiency - 14.2%
Combined efficiency - 38.7%

Note: These are pike whose location was known throughout the entire experiment. All pike were tagged at the upstream trap and recaptured at the fishway cages, the downstream trap or in gill nets at the end of the experiment.

Table 22. Estimate of minimum aggregate efficiency for northern pike, Experiment Two, 1990.

Tagged pike available for ascent (see note):

1414
1418
1420
7054
7095,7201 *
7098
7099 **
7203 *
7205 *
7206 *
7208 *
7210 **
7212

7213
7214 **
7215
7216 **
7217 **
7218
7219
7220
7221 *
7222 *
7223
7224 *
7225

7226
7227
7228
7229 **
7230
7235
7236
7237
7238
7239 **
7241
7243
7244

7245 *
7247 *
7248
7251
7252[1045] *
7253
7255
7258
7306
7316
7317
7327
7332

7333 *
7334
7335
7337
7338
7352
7354
7363
7365
7367

* Ascended steeppass fishway
**Ascended standard Denil fishway

Standard Denil ascents - 12
Standard Denil ascents - 7
Total ascents - 19
Number available for ascent - 62

Steeppass efficiency - 19.4%
Standard Denil efficiency - 11.3%
Combined efficiency - 30.7%

Note: These include pike whose locations were known for the entire experiment ie., they were tagged at the upstream trap and recaptured at the fishway cages, the downstream trap or in the gill nets at the end of the experiment. Also included are fifteen pike that were tagged at the upstream trap but that did not ascend the fishways and were not recaptured at any other location.

Table 23. Passage efficiencies for northern pike in steeppass and standard Denil fishways at low flow, Experiment Two, 1990.

Tagged pike available for ascent:

1414
1418
1420
7099**
7214**
7215
7216**
7217**
7218
7219
7220
7221 *
7222 *
7223
7224 *
7226
7227
7228
7229 **
7238
7239 **
7248
7251
7253
7255
7258
7332
7333
7335
7337
7338
7352
7354
7365

* Ascended steeppass fishway
**Ascended standard Denil fishway

Steeppass ascents - 3
Standard Denil ascents - 6
Total ascents - 9
Number available for ascent - 34

Steeppass efficiency - 9%
Standard Denil efficiency - 18%
Combined efficiency - 27%

Table 24. Passage efficiencies for northern pike in steeppass and standard Denil fishways during high flow, Experiment Two, 1990.

Tagged pike available for ascent:

1420
7054
7095,7201 *
7203 *
7205 *
7206 *
7208 *
7210**
7226
7235
7236
7245 *
7247 *
7248
7251
7252[1045] *
7253
7255
7258
7327
7332
7333
7334 *
7335
7337
7338
7352
7354

* Ascended steeppass fishway
**Ascended standard Denil fishway

Steeppass ascents - 9
Standard Denil ascents - 1
Total ascents - 10
Number available for ascent - 28

Steeppass efficiency - 32%
Standard Denil efficiency - 4%
Combined efficiency - 36%

Steeppass, low flow - 9%

Steeppass, high flow - 32%

6.5.4.3 Period Efficiencies

Period efficiencies are summarized in Table 25. During the twelve 12-hour periods of Experiment Two, the number of tagged pike available for ascent ranged from one to sixteen and the number of pike ascending in any period varied from zero to six. The calculated period efficiencies ranged from zero to 100%. Period efficiencies for the standard Denil fishway varied from zero to 50% while values ranged from zero to 83.3% for the steeppass fishway.

For each fishway and flow combination, the mean period efficiency was calculated from the applicable periods. The mean period efficiencies for each fishway and flow combination are:

Standard Denil, low flow - 15.3%
Standard Denil, high flow - 2.8%
Steeppass, low flow - 4.5%
Steeppass, high flow - 21.1%

These values represent the average percentage of pike available for ascent, that actually ascended the fishways, during a twelve hour period.

Table 25. Period efficiencies for northern pike, Experiment Two, 1990.

Period	Number Available	Flow Level	# Ascents Steeppass	# Ascents Standard	# Ascents Total	% Ascents Steeppass	% Ascents Standard	% Ascents Total
21	2	L	0	1	1	.0	50.0	50.0
22	6	H	5	1	6	83.3	16.7	100.0
23	1	H	0	0	0	.0	.0	.0
24	16	L	2	4	6	12.5	25.0	37.5
25	7	L	1	0	1	14.3	.0	14.3
26	6	L	0	1	1	.0	16.7	16.7
27	3	H	0	0	0	.0	.0	.0
28	9	H	3	0	3	33.3	.0	33.3
29	6	L	0	0	0	.0	.0	.0
30	10	H	1	0	1	10.0	.0	10.0
31	8	H	0	0	0	.0	.0	.0
32	8	L	0	0	0	.0	.0	.0

Mean Period Efficiencies (%)

	High Flows	Low Flows	Mean
Steeppass	21.1	4.5	12.8
Standard	2.8	15.3	9.0
Combined	23.9	19.7	21.8

6.6 Comparison of Physical Characteristics of Northern Pike

6.6.1 Comparison of Pike Ascending the Standard Denil and Steeppass Fishways

6.6.1.1 Length

The length frequency distributions for northern pike ascending the standard Denil and steeppass fishways during Experiment Two are shown in Figures 16 and 17, respectively. The mean fork length of pike ascending the standard Denil fishway was 50.2 cm whereas pike ascending the steeppass fishway had a mean fork length of only 46.9 cm. However, a t-test (Appendix 12) showed that this size difference was not significant (t = 1.040, P > .1).

6.6.1.2 Sex

The number of pike of each sex ascending each fishway is shown in Table 26. Only those fish for which sex could be positively determined by expression of sexual products were included. A G-test indicated that there was no preference by sex for either fishway (G = .538, P >.1).

6.6.1.3 Spawning Condition

Table 27 shows the number of pike ascending each fishway during Experiment Two, according to spawning condition. Only pike for which spawning condition could be definitely determined were included. A G-test showed that there was no difference in spawning condition between pike

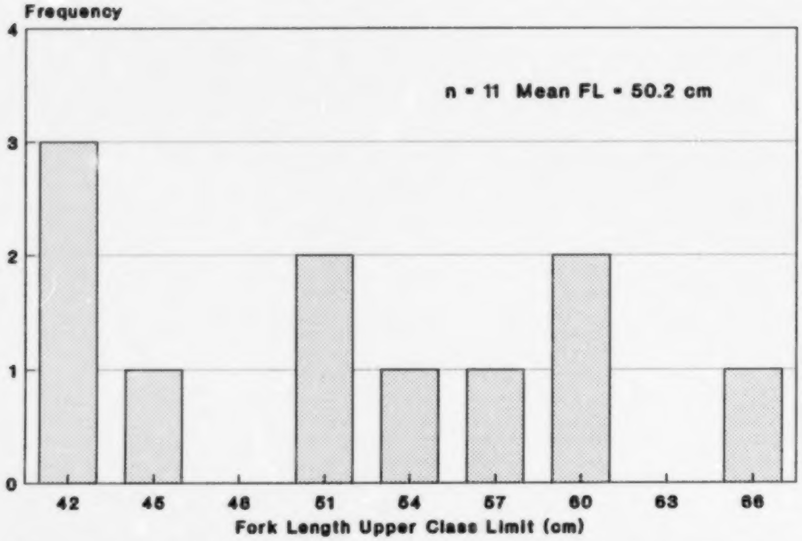


Figure 16. Length frequency distribution of pike ascending standard Denil fishway, Experiment Two, 1990

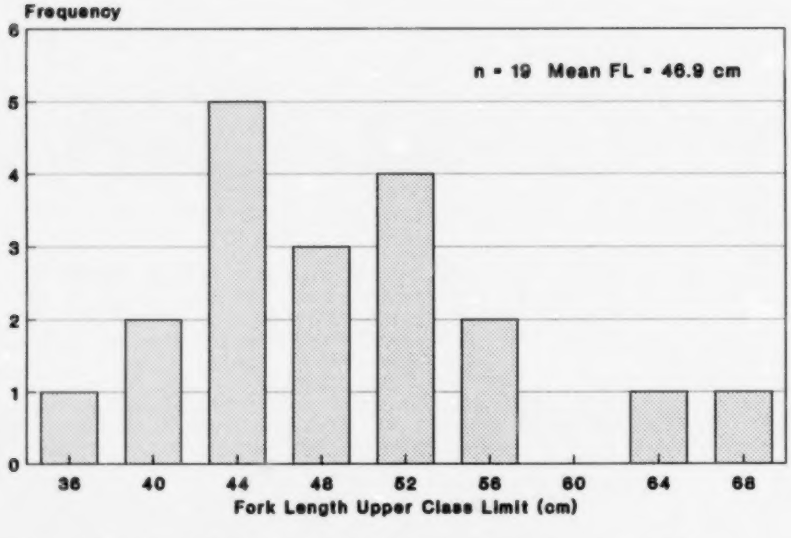


Figure 17. Length frequency distribution of pike ascending steeppass fishway, Experiment Two, 1990

Table 26. Comparison of sex of northern pike ascending the standard Denil and steeppass fishways during Experiment Two, 1990.

Sex	Steeppass	Standard
Male	10	8
Female	3	1

G = .538

Critical value of X^2 = 3.841 at P = .05

Results are not significant.

Table 27. Comparison of spawning condition of northern pike ascending the standard Denil and steeppass fishways during Experiment Two, 1990.

Spawning Condition	Standard	Steeppass
Green	0	0
Expressing	4	3
Ripe	5	4
Spent	2	8

G = 3.488

Critical value of X^2 = 5.991 at P = .05, df = 2

Results are not significant.

ascending the two fishways (G = 3.488, P >.05).

6.6.2 Comparison of Pike Ascending the Fishways and Pike Not Ascending the Fishways

There was no difference in length, sex, or spawning condition between pike ascending the two fishways. Data from these two groups were then combined to represent all pike ascending the fishways in Experiment Two and compared to pike that were available during Experiment Two but did not ascend the fishways.

6.6.2.1 Length

The length frequency distribution for pike ascending the fishways is shown in Figure 18 and the length frequency distribution for nonascending pike is shown in Figure 19. The mean fork length for pike ascending the fishways was 48.1 cm whereas nonascending pike had a mean fork length of 53.0 cm. A t-test (Appendix 12) showed that this difference was significant ($t = 2.322$, $P < .05$).

This difference suggests that smaller pike are more capable of ascending the fishways or more likely to ascend than larger pike. If so, progressively smaller pike would be expected to ascend the fishways as water velocities increase until some upper limit in swimming ability is reached. This was tested by comparing the size of pike ascending at low water velocities to the size of pike

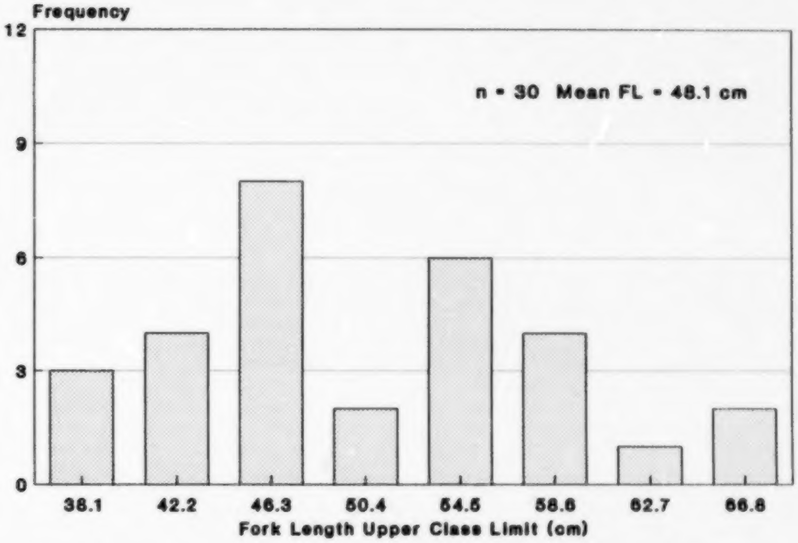


Figure 18. Length frequency distribution of pike ascending standard Denil and steeppass fishways, Experiment Two, 1990

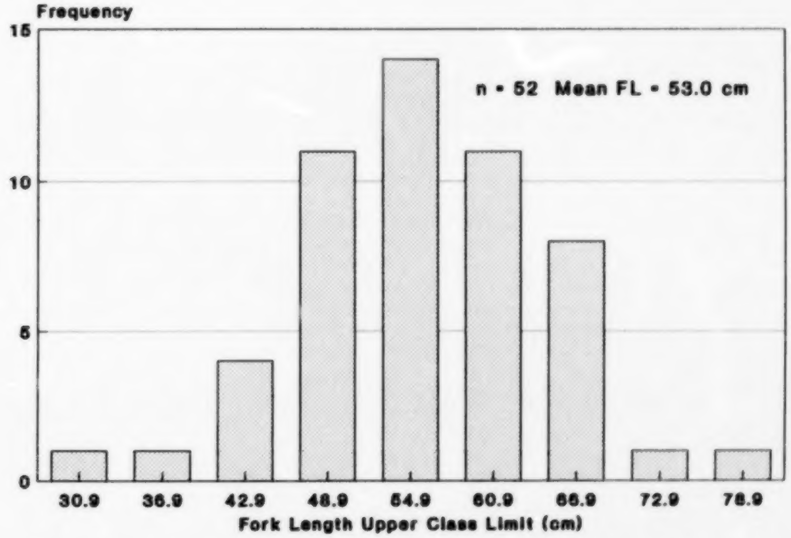


Figure 19. Length frequency distribution of nonascending pike, Experiment Two, 1990

ascending at high water velocities (Appendix 12). Pike ascending the fishways at low velocities averaged 50.8 cm fork length whereas pike ascending at high velocities averaged only 45.5 cm. The difference in size was not, however, significant ($t = 1.80$, $P > .05$).

A further comparison involved nonascending pike and pike that ascended the fishways at high flow (Appendix 12). Nonascending pike averaged 53.0 cm fork length whereas ascending pike were considerably shorter at 45.5 cm. A t-test showed that this difference was significant ($t = 2.82$, $P < .01$).

6.6.2.2 Sex

More males than females ascended the fishways in Experiment Two (Table 28). However, this difference was not significant ($G = .312$, $P > .5$) and arose due to the high ratio of males to females in the fishway vicinity.

6.6.2.3 Spawning Condition

There was no difference in spawning condition of pike ascending the fishways and pike that did not ascend the fishways (Table 29).

6.7 Swimming Speed of Northern Pike

6.7.1 Depths of Ascent

Two observations were made of the swimming depth of

Table 28. Comparison of sex of ascending and nonascending northern pike during Experiment Two, 1990.

Sex	Ascending Pike	Nonascending Pike
Male	18	34
Female	4	5

G = .312

Critical value of X^2 = 3.841 at P = .05

Results are not significant at P = .05

Table 29. Comparison of spawning condition of ascending and nonascending northern pike in Experiment Two, 1990.

Spawning Condition	Ascents	Nonascents
Expressing	7	13
Ripe	9	13
Spent	10	21

G = .422

Critical value of X^2 = 5.991 at p = .05

Results are not significant at P = .05

pike in the fishways. Pike #7233 and pike #7240 both ascended the steeppass fishway during high flow and passed under the colored bar. These pike were 52.0 cm and 36.6 cm fork length, respectively. These events occurred with a fishway operating depth of .42 metres. With this depth of flow, the predicted water velocity below the bar varies from .78 m/sec just above the fishway floor to .50 m/sec just below the bar. Forward speed of both pike was estimated at 20 cm/sec. The swimming speed over the 7.3 metre channel distance is therefore estimated between .7 m/sec and 1.0 m/sec.

6.7.2 Timed Ascents

Timed ascents of the upper channel of the standard Denil fishway were obtained for four pike in 1989 (Table 30). The estimated swimming speed (water velocity plus forward velocity of the fish) varied from .61 m/sec to .87 m/sec. In 1990, one pike ascent was timed (Table 30). This fish ascended near the surface in the standard Denil fishway during low flow. Depending on the exact depth at which it swam, it encountered velocities ranging between .29 and .46 m/sec and its swimming speed was calculated between .62 and .79 m/sec.

One other observation of note was a pike that attempted to ascend the standard Denil fishway at the surface during a low flow period. It ascended about two-thirds of the length

Table 30. Timed fishway ascents by northern pike in 1989 and 1990.

Year	Tag #	Fork Length (cm)	Depth of Ascent (m)	Velocity at Depth (m/sec)	Ascent Time (sec)	Distance (m)	Forward Speed (m/sec)	Total Speed (m/sec)	Total Speed (l/sec)
1989	1109	55	.06	.35	10	5.2	.52	.87	2
	1111	53	.06	.35	10	5.2	.52	.87	2
	1129,1130	77	.08	.35	20	5.2	.26	.61	1
	1135	59	.08	.35	20	5.2	.26	.61	1
1990	7229	64	.2-.25	.29-.46	22	7.3	.33	.62-.79	1.0-1.3

of the uppermost channel and then was swept back to the resting pool. The water velocity at the surface was approximately .46 m/sec. This pike could not be captured for measurement but was estimated to be about 45 cm in length.

6.8 Delay Times

6.8.1 Ascending Pike

The delay time for ascending pike is the time elapsed between arrival of a fish in the study area and its ascent of a fishway. During Experiment Two, delay times were determined for seven pike that used the standard Denil fishway and twelve pike that used the steeppass fishway (Tables 31 and 32). Both mean and median delay times were determined. The median delay time is more meaningful as a measure of central tendency since it reduces the effects of extreme outliers.

The median delay time for pike ascending the standard Denil fishway was 2.75 hours. This is similar to the median delay time of 3.0 hours for pike ascending the steeppass fishway. Though sample numbers are small, results suggest that delay times are related to flow regimes in the fishway. For the standard Denil fishway, the median delay time for low flow periods was 3.5 hours while the median delay time for high flow periods was slightly less at 2.75 hours. For the steeppass fishway, the median delay time was 3.0 hours

Table 31. Passage delay times for northern pike ascending the standard Denil fishway during Experiment Two, 1990.

Tag #	Release to Pool		Recapture in Cage		Length of Delay (h)	Flow Regime	
	Date	Time	Date	Time		Release	Recapture
7099	05/13/90	545 PM	05/13/90	1000 PM	4.25	L	L
7210	05/14/90	915 AM	05/14/90	1030 AM	1.25	H	H
7229	05/15/90	1000 AM	05/15/90	1200 PM	2	L	L
7216	05/15/90	900 AM	05/15/90	1200 PM	3	L	L
7214	05/15/90	900 AM	05/15/90	700 PM	10	L	L
7217	05/15/90	900 AM	05/15/90	1030 AM	1.5	L	L
7239	05/16/90	830 AM	05/16/90	1100 AM	2.5	L	L

Mean delay time - 3.5 hours (n = 7)
Mean delay time at high flow - 1.25 hr (n = 1)
Mean delay time at low flow - 3.9 hours (n = 6)

Median delay time - 3.0 hours (n = 7)
Median delay time at high flow - 1.25 hours (n = 1)
Median delay time at low flow - 3.0 hours (n = 6)

Table 32. Passage delay times for northern pike ascending the steeppass fishway during Experiment Two, 1990.

Tag #	Release to Pool		Recapture in Cage		Length of Delay (h)	Flow Regime	
	Date	Time	Date	Time		Release	Recapture
7095,7201	05/13/90	530 PM	05/14/90	200 PM	20.25	L	H
7208	05/14/90	900 AM	05/14/90	1030 AM	1.50	H	H
7205	05/14/90	845 AM	05/14/90	145 PM	5.00	H	H
7206	05/14/90	845 AM	05/14/90	1030 AM	1.75	H	H
7203	05/14/90	830 AM	05/14/90	1000 AM	1.50	H	H
7222	05/15/90	930 AM	05/15/90	1030 AM	1.00	L	L
7221	05/15/90	930 AM	05/15/90	100 PM	3.50	L	L
7224	05/15/90	930 AM	05/16/90	215 AM	16.75	L	L
7252[1045]	05/17/90	830 AM	05/17/90	1100 AM	2.50	H	H
7247	05/17/90	815 AM	05/17/90	1100 AM	2.75	H	H
7245	05/17/90	815 AM	05/17/90	1100 AM	2.75	H	H
7334	05/18/90	830 AM	05/18/90	330 PM	7.00	H	H

Mean delay time - 6.75 hours (n = 12)
Mean delay time at high flow * - 3.1 hours (n = 8)
Mean delay time at low flow* - 7.1 hours (n = 3)

Median delay time - 2.75 hours (n = 12)
Median delay time at high flow* - 2.75 hours (n = 8)
Median delay time at low flow* - 3.5 hours (n = 3)

*Using only fish for flow regimes that are consistent from time of release to time of ascent for low flow periods but was only 1.25 hours during high flow periods.

Overall, the median delay time during Experiment Two was 2.75 hours and the mean delay time was 4.8 hours. The minimum delay time observed was one hour and the maximum was 20.25 hours.

6.8.2 Nonascending Pike

The delay time for nonascending pike is the time elapsed between arrival of a fish in the study area and its departure from the study area. The delay times, or turnaround times, for nonascending pike are greater than for ascending pike. The median turnaround time in Experiment Two was 18 hours and the mean turnaround time was 28.4 hours (Table 33). The minimum turnaround time was near zero as one pike released from the upstream trap was found in the downstream trap when it was checked a half hour later. At the other extreme, one pike captured in a gill net before Experiment Two was recaptured in the downstream trap six days later.

6.9 Migrations

6.9.1 Tag Recoveries

Nine pike tagged in 1989 were caught by anglers or commercial fishermen subsequent to the 1989 field season or were recaptured at the fishways in 1990. Dates and

Table 33. Turnaround time for nonascending northern pike, Experiment Two, 1990.

	Release to Pool From Upstream Trap		Recapture in Down-Stream Trap		Length of Delay (h)
Tag #	Date	Time	Date	Time	
1414	05/13/90	700 PM	05/14/90	700 AM	6
1418	05/15/90	700 AM	05/16/90	700 PM	30
1420	05/17/90	700 AM	05/18/90	700 AM	18
7054*	05/09/90	700 AM	05/15/90	700 AM	138
7066*	05/10/90	700 PM	05/11/90	700 PM	18
7215	05/15/90	700 AM	05/15/90	700 PM	6
7218	05/15/90	700 AM	05/16/90	700 PM	30
7219	05/15/90	700 AM	05/15/90	700 PM	6
7220	05/15/90	700 AM	05/15/90	700 AM	0
7223	05/15/90	700 AM	05/16/90	700 AM	18
7226	05/15/90	700 AM	05/17/90	700 AM	42
7227	05/15/90	700 AM	05/16/90	700 AM	18
7228	05/15/90	700 AM	05/16/90	700 PM	30
7235	05/16/90	700 PM	05/17/90	700 AM	6
7248	05/17/90	700 AM	05/19/90	700 AM	42
7251	05/17/90	700 AM	05/18/90	700 AM	18
7253	05/17/90	700 AM	05/18/90	700 AM	18
7255	05/17/90	700 AM	05/18/90	700 AM	18
7258	05/17/90	700 AM	05/18/90	700 AM	18
7327	05/18/90	700 AM	05/18/90	700 PM	6
7333	05/18/90	700 AM	05/20/90	700 AM	42
7335	05/18/90	700 AM	05/20/90	700 AM	42
7337	05/18/90	700 AM	05/20/90	700 AM	42
7338	05/18/90	700 AM	05/20/90	700 PM	54
7352	05/18/90	700 AM	05/20/90	700 AM	42
7354	05/18/90	700 AM	05/20/90	700 AM	42
7365	05/19/90	700 AM	05/20/90	700 AM	18

Mean turnaround time - 28.4 hours (n = 27)
Median turnaround time - 18 hours (n = 27)

*Gill net capture

Note - The exact time that pike left the pool could not be determined. The downstream trap was emptied every 12 hours and all pike in the trap were assigned an exit time corresponding to the midpoint of the previous time period.

locations of capture are given in Table 34 and map locations are shown in Figure 20. From these tag recoveries, it appears that pike dispersed in all directions from the fishways and travelled considerable distances. The maximum distance travelled was 190 kilometres for a pike captured on the Saskatchewan River near The Pas, Manitoba.

Three pike tagged at the study site in 1989 returned in 1990. On May 11, a male pike with tag #1044 was captured in the exit cage of the steeppass fishway. This pike measured 62.4 cm in length in 1989 and 64.4 cm in 1990, an increase of two centimetres. This pike was retagged #7077 and released to the marsh.

On May 17, 1990, a pike with tag #1045 was captured in the upstream trap of the counting fence. This pike was 50.6 cm in length in 1989 and had grown by 4.2 cm to a length of 54.8 cm in 1990. It was retagged #7252 and released to the pool. It subsequently ascended the steeppass fishway but was returned to the pool and it left the area on May 18. On September 3, 1990, it was caught by an angler at the E. B. Campbell Dam.

On May 20, a pike with tag #1080 was captured in the downstream trap. This pike measured 57.4 cm in 1989 and 61.0 cm in 1990, an increase of 3.6 cm. It was retagged #7372 and released.

Table 34. Recaptures of northern pike tagged during 1989 field season.

Tag #	Date Captured	Location	Distance Travelled
1097,1098	May, 1989	Gun Creek	3 k
1106	May 25, 1989	Gun Creek	3 k
1100	July 31, 1989	E. B. Campbell Dam	65 k
1112	April 4, 1990	Saskatchewan River	190 k
1147	May, 1990	Cross Lake	45 k
7077[1044]	May 11, 1990	Study Site	Unknown
7252[1045]	May 17, 1990	Study Site	Unknown
	Sept 3, 1990	E. B. Campbell Dam	65 k
7372[1080]	May 20, 1990	Study Site	Unknown
1031	March 1990	Whitey Narrows	55 k

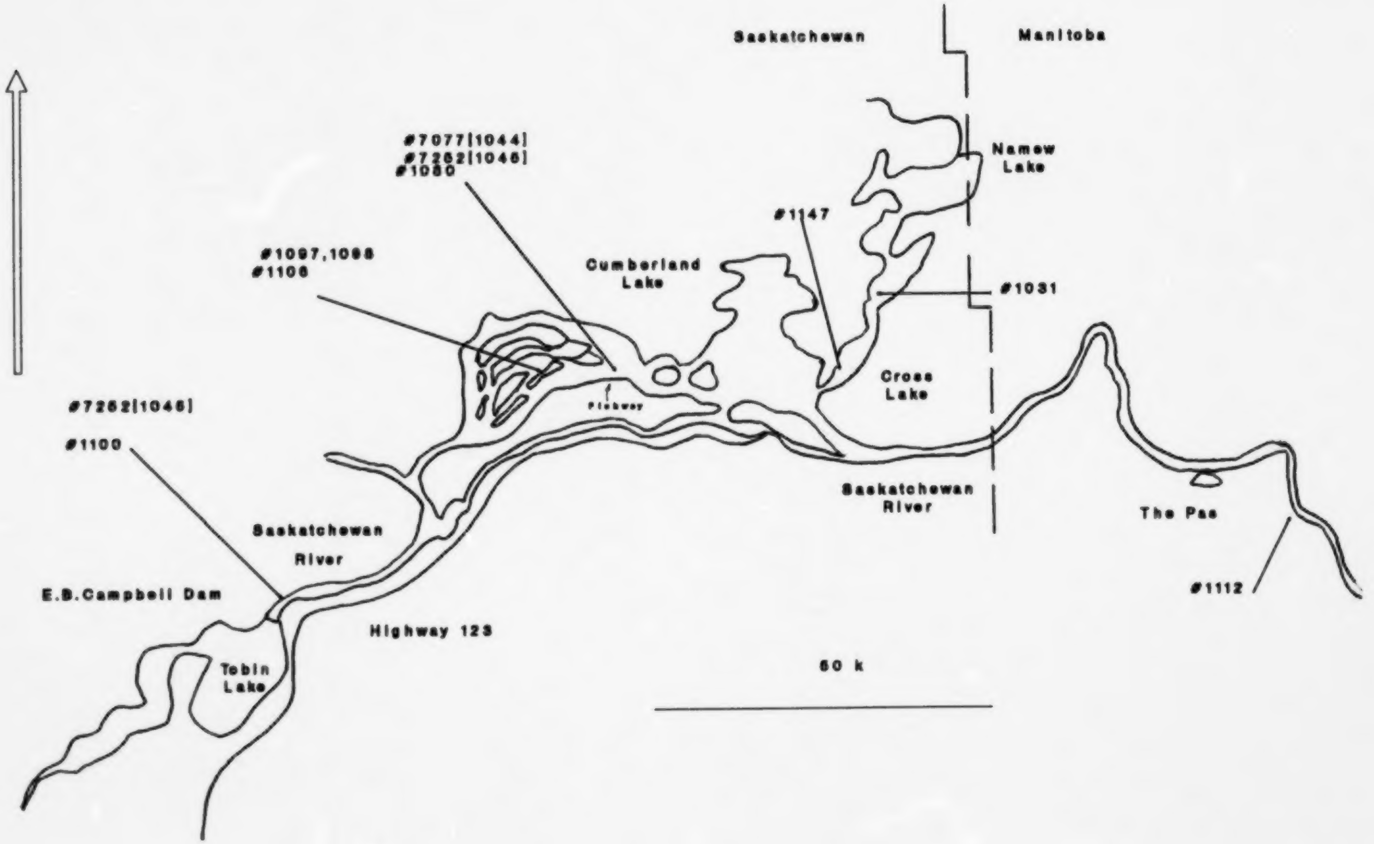


Figure 20. Locations of recaptures of northern pike tagged at Sisip fishways in 1989 field season.

6.10 Other Species

There were no fishway ascents by species other than northern pike in 1989 or 1990.

7. Discussion

7.1 Fishway Passage Comparisons

Fishway passage results in the two experiments can be largely explained by two aspects of behaviour. The first is the reaction of fish to different water velocities. Migrating fish tend to follow the strongest flow when confronted with two options. Weaver (1963) found that when presented with a choice of velocity of 1.22 m/sec or 2.44 m/sec, steelhead (*Oncorhynchus mykiss*), coho salmon (*O. kisutch*) and chinook salmon (*O. tshawytscha*) all preferred to swim against the higher velocity. Preference for higher velocity flows has also been shown for Arctic grayling (Tack and Fisher 1977).

Many nonsalmonid species have been shown to prefer high velocity flows over low velocities. Pavlov (1989) demonstrated under laboratory conditions that as velocities in an experimental canal increased, the number of fish entering it also increased until velocities began to exceed the swimming ability of the fish. These results were confirmed for common bream (*Abramis brama*) and zander (*Stizostedion lucioperca*) at a floating fish pass in the U.S.S.R. (Pavlov 1989). Higher passage rates for walleye

(Katopodis et al. 1991) and pike (Dunn 1983) have been noted on days with significantly greater discharge and mean velocity at two fishways in western Canada. Comparison of fish passage at three fishways in Alberta suggested that northern pike preferred to swim against higher water velocities when given a choice (Schwalme et al. 1985). Nelson (1983) observed that pike chose higher velocity zones (2.1-2.4 m/sec) over lower velocity zones (1.5-1.9 m/sec) when negotiating a road washout during a spawning run in central Alberta.

The second factor is the behaviour of pike in the resting pools. Low water flow through the fishways in 1989 resulted in calm, clear water in the resting pools which provided an opportunity to observe pike behaviour. When pike entered a resting pool they immediately descended to the bottom and remained there for fifteen to thirty minutes. Eventually, they would rise slowly toward the discharge of the next channel. The discharge was always approached from below the fishway floors rather than from in front at the water surface. With this approach pattern, the decision of whether to enter a channel must be based on characteristics of the flow at the floor of the fishway.

7.1.1 Experiment One

For both low flow and high flow conditions, there was no significant difference in the number of ascents between fishways. This indicates that pike are equally capable of ascending standard Denil and steeppass fishways.

For the standard Denil fishway, there was no difference in pike passage between low and high flows. However, there was a very significant difference for the steeppass fishway, with more ascents during high flow periods. This difference may be explained by the tendency of pike to swim against stronger water velocities. The entry of pike to a fishway channel is in response to the stimulus of the water flow. A stronger stimulus should elicit a stronger response so greater water velocities should stimulate more fish to enter the fishway. The pike encounter the water flow at the fishway floor. At this level, the water velocity at low flow averaged .46 m/sec compared to .76 m/sec at high flow (Table 11). The higher water velocity at high flow may have stimulated more pike to enter and ascend the fishway channel and resulted in the observed difference in passage at low and high flows.

There was no significant difference in pike ascents between flows for the standard Denil fishway. In this fishway, there was relatively little difference in velocity at the fishway floor between low and high flows. Velocity at low flow averaged .16 m/sec while velocity at high flow was only slightly higher at .22 m/sec (Table 11). In addition, the configuration of the lower end of the standard Denil fishway channel resulted in a cascade effect in the resting pool which caused considerable surface turbulence. The additional stimulus of the surface turbulence and the relatively small difference in floor velocities between flows may have moderated the difference in passage at low and high flows.

7.1.2 Experiment Two

In Experiment Two, fish could choose which fishway to enter, based on flow patterns at the entrances. Thus, Experiment Two not only tested the ability of pike to ascend the fishways but also their preference for each fishway.

Consistent with Experiment One, there was no difference in pike passage between fishways at low flow. However, there were significantly more ascents of the steeppass fishway relative to the standard Denil fishway at high flows.

Passage at low flow was similar for both fishways in spite of the steeppass fishway having a higher floor velocity than the standard Denil fishway (Table 11, Figure 9). The higher velocity should have stimulated more fish to enter the steeppass fishway. However, the attraction of the greater surface turbulence at the exit of the standard Denil fishway may have moderated any expected differences.

Under high flow conditions, the difference in floor velocities of the two fishways is greater (Table 11, Figure 9). Average floor velocity for the steeppass fishway was

.76 m/sec but only .22 m/sec for the standard Denil fishway. As suggested earlier, pike chose which fishway to enter based on the velocity at the fishway floor. The substantially higher velocity in the steeppass fishway stimulated more pike to enter this fishway relative to the standard Denil fishway.

Although there was a difference in passage between fishways at high flow in Experiment Two, there was no difference in Experiment One. This may be explained by the choices available to the pike in the second experiment but not in the first. In Experiment One, pike could not choose which fishway to enter from the upper resting pool. Although the standard Denil fishway had a lower floor velocity than the steeppass fishway additional pike in the standard Denil resting pool may have entered the fishway due to the additional stimulus of the surface turbulence. There was therefore little difference in ascents between fishways. In Experiment Two, however, pike could choose between fishways and most likely chose the steeppass fishway due to the greater stimulus of the higher floor velocity.

There was no significant difference in ascents between flows for either fishway in Experiment Two. This differs from Experiment One where a significant difference was found for the steeppass fishway. This may be due to the greater number of pike available for ascent during low flow periods in Experiment Two (45 compared to 37 during high flow periods). Had there been equal numbers available for both flow conditions, it is possible that more pike would have ascended the steeppass fishway during high flows.

In both experiments, results are consistent in that the highest number of pike ascents occurred in the steeppass fishway with high flow and second greatest passage occurred in the standard Denil fishway with low flow.

In summary, results indicate that northern pike are equally capable of ascending both fishways but prefer to use the steeppass fishway at high flows and that passage success is increased with higher flows.

7.2 Physical Characteristics

7.2.1 Comparison Between Fishways

No differences were found in comparisons of pike ascending the two fishways with respect to length, sex, or spawning condition. Major differences had not been expected due to similarities in the general configuration, discharges and velocities of the two fishways.

7.2.2 Comparison Between Ascending and Nonascending Pike

7.2.2.1 Length

Length comparisons indicated that pike ascending the fishways were smaller than pike not ascending the fishways. The difference in size was more pronounced when pike ascending at high flow were compared to nonascending pike.

Other studies have suggested some size selectivity by Denil fishways. Fernet (1984) found that pike ascending the Fawcett Lake Denil fishway averaged 47.2 cm fork length compared to an overall population average of 50.3 cm. Halstead (1984), in an earlier study, also noted selection for smaller pike at this fishway. Schwalme and MacKay (1985) found that pike ascending Denil and vertical slot fishways at Lesser Slave Lake were significantly shorter than pike seined from below the fishways.

Selection by fishways for smaller pike cannot be a result of differences in swimming ability. Larger fish generally are capable of greater swimming speeds (Beamish 1978, Brett 1965, Jones et al. 1974) so the larger pike in the study were probably capable of ascending the fishways. The tendency for smaller pike to ascend the fishways may be a behavioural response in which smaller or younger pike exhibit a stronger reaction to high water velocities.

7.2.2.2 Sex

The similarity in passage rates for males and females suggests that both sexes have similar swimming abilities and motivation. It is possible that a larger sample would show a difference since male and female northern pike generally have divergent growth rates after maturity (Scott and Crossman 1973) and smaller pike tend to be more disposed to ascend the fishways. With larger samples, standard Denil and steeppass fishways may therefore pass proportionately more males than females.

7.2.2.3 Spawning Condition

No difference in spawning condition was found between ascending and nonascending pike. It is notable that ascending pike were closely divided among expressing, ripe and spent conditions. If continuation of a spawning migration was the major motivation for fishway ascent, ascending pike should be mainly prespawners and nonascending pike should include a greater proportion of postspawners.

Postspawning pike have been noted ascending other fishways in western Canada (Watters 1980, Katopodis et al. 1991). These pike may have been part of a postspawning feeding migration or simply the incidental passage of small numbers of pike from a larger feeding congregation below the fishways.

7.3 Efficiency

The maximum estimate of aggregate efficiency was 38.7% while the minimum estimate was 30.7%. The minimum estimate was reached by including as available for ascent, thirteen pike that entered the pool from the upstream trap but which were not later recaptured. This reduced the efficiency estimate but the resulting estimate is likely too conservative. There were an additional eleven pike captured at the fishway traps during Experiment Two that were untagged. This suggests that there was two way movement of pike through a hole in the counting fence (a ten centimetre diameter hole was found when the centre lead was lifted at the end of the study). It appears that undetected exits of pike at this point were roughly balanced by undetected entries and the maximum efficiency estimate of 38.7% is reasonable.

The aggregate efficiency estimate is higher than the efficiency estimate would be for either fishway operating alone. If either fishway were operated alone, some, but not all, pike would ascend. Speculation about the efficiency of either fishway operated alone must recognize that the aggregate efficiency estimate of 38.7% represents the maximum possible efficiency under these circumstances and the true efficiency would be lower.

The efficiency estimate for pike passage in these fishways far exceeds those for other fishways in western Canada. Halstead (1984) determined the efficiency of a standard Denil fishway at Fawcett lake, Alberta, to be only 2.3% with respect to northern pike. Fernet (1984) estimated efficiency for pike at 10.4% for the same fishway after improvements were made to its design. An extremely low efficiency of only 0.2% was estimated for the pool and weir fishway formerly in place at Fawcett Lake (Minchau 1980). A pool and weir fishway at Gregoire Lake had an estimated efficiency of 6.4% for pike (Watters 1980).

The chief reason for the superior efficiency of the fishways in this study is likely the absence of competing attraction flow. In the previously cited studies, the fishways were located adjacent to spillways whereas no spillway flow was present in this study. Pike are easily diverted by competing flow and are attracted to the highest discharges in the vicinity (Dunn 1983, Fernet 1984, Halstead 1984). Absence of competing attraction flow in the present study allowed pike to easily locate the fishway entrance.

Entrance conditions are related to competing attraction flow. Unsuitable location of the entrances in relation to competing attraction flows probably reduced passage at the Fawcett Lake fishway (Halstead 1984, Fernet 1984) but was not a factor at the Siisiip fishways.

7.3.2 Comparison of Efficiency in Experiments One and Two

The aggregate efficiency in Experiment One was 4.7%, approximately one-eighth the value estimated for Experiment Two. This may be attributed to the difference in capture methods in the two experiments. In Experiment One, the fish were captured in gill nets whereas in Experiment Two they were captured in trap nets. Fish were entangled in the nets for up to one hour before being tagged and released. No mortalities resulted from this capture method but the added stress may have affected subsequent behaviour of these pike, reducing their migratory urge.

7.3.3 Fishway/Flow Regime Efficiencies

These efficiency values indicate the effectiveness of each fishway and flow regime combination for passage of northern pike. Comparisons of pike passage in Sections 6.4 and 6.5 were based on absolute numbers regardless of availability. In this section, passage is expressed relative to the number of pike available. Results show that the best combination of fishway and flow regime is the steeppass fishway at high flow, with an efficiency of 32%. Next is the standard Denil fishway at low flow (18%) followed by the steeppass fishway at low flow (9%) and the standard Denil fishway at high flow (4%).

These estimates lend credence to the observations of absolute passage numbers in Experiment Two in that the efficiencies of the fishway/flow combinations are ranked in the same order as the absolute passage numbers.

The efficiency of the steeppass fishway operated at high flow was 32%. If the steeppass fishway had operated alone, some of the pike that ascended the standard Denil fishway may have ascended the steeppass fishway. In that case, the efficiency would have been 36%. Thus, the steeppass fishway operated at a mean depth of flow of 41 cm, has an efficiency between 32% and 36%. This is about three and one-half times greater than the standard Denil fishway at Fawcett Lake (Fernet 1984).

The second best efficiency was for the standard Denil fishway operated at low flow (18%). If it had been operated alone and all the fish that ascended the steeppass fishway had ascended it, the efficiency would have been 27%. Thus, the efficiency of the standard Denil fishway, operated at a mean depth of 26 cm, lies between 18% and 27%. Similarly, the efficiency of the steeppass fishway operated alone at low flow would lie between 9 and 27% and the standard Denil fishway operating alone at high flow would have an efficiency between 4 and 32%.

Two conclusions can be reached from these efficiency estimates. First, the highest efficiency value is for the steeppass fishway, suggesting that the steeppass fishway is preferred by northern pike. However, it should be noted that pike are equally capable of ascending both types of fishways. If only one type of fishway is available, the efficiencies may be comparable regardless of fishway type. Second, even the value for the standard Denil fishway (at low flow) exceeds that from any other study for which estimates are available. This indicates that other factors such as competing attraction flow and entrance location may figure significantly in fishway success.

7.3.4 Period Efficiencies

The period efficiency values varied greatly, with lower values occurring near the end of the study. The average period efficiency was fairly high at 21.8%. This is a reflection of the high overall efficiency of the fishways and the short delay time.

7.4 Swimming Speed of Pike

Burst speed is defined as the velocity that can be maintained by fish for periods of less than 20 seconds (Beamish 1978). Northern pike are well adapted for burst swimming. Muscle tissue is predominantly anaerobic white muscle which is well suited to burst swimming (Bone 1966) and pike body configuration further lends itself to fast start performance (Weihs and Webb 1983).

Burst speed of pike has been estimated at up to 4.0 m/sec (Nelson 1983, Stringham 1924) but this speed can be maintained for only about one second (Nelson 1983). As the time span increases, burst speed decreases. Nelson (1983) measured burst speed of pike for two seconds at 3.3 m/sec, for ten seconds at 1.2 m/sec and for 14 seconds at 0.9 m/sec. Halstead (1989) measured the speed of one pike at 1.3 m/sec for 15 seconds. Little information is available on pike swimming speeds for slightly longer time periods but it appears that a speed of 0.8 m/sec can be maintained for up to 130 seconds (Orr, unpublished data).

Observations of swimming speeds of pike at the study site were limited in number but showed that pike were capable of speeds of 0.6 m/sec to 1.0 m/sec over periods of ten to 22 seconds. These speeds are comparable to estimates of Nelson (1983). Note that these estimates do not necessarily indicate maximum swimming ability since the pike may only exert themselves to the extent required for fishway ascent.

7.5 Delay Times

Very short delay times were observed in this study, in contrast to other studies in western Canada. The mean delay time for pike at the Fawcett lake fishway was 14.5 days in 1982 (Halstead 1984) and 9.9 days in 1983 (Fernet 1984). The mean delay time at the Cowan Dam fishway in 1985 was 16.2 days. By comparison, the mean delay time at the Siisiip fishways was only 4.8 hours.

The short delay time in this study was likely due to the absence of competing attraction flow. Both the Fawcett Lake fishway and the Cowan Dam fishway were operated adjacent to water control structures which were discharging at rates up to twenty times the outflow of the fishways (Fernet 1984, Katopodis et al. 1991). This competing flow would have made it difficult for pike to locate the fishway entrances. In the case of the Cowan Dam fishway, longer delay times may have been in part due to less motivation. Peak passage at this structure occurred at water temperatures of 17 - 18°C and virtually all pike were spent

(Katopodis et al. 1991). Concentrations of pike below the fishway may have been post-spawning feeding aggregations and motivation for upstream migration would have been low relative to pike at the Siisiip fishways.

The median delay time for ascending pike in this study was 2.75 hours. However, the median turnaround time for nonascending pike was considerably longer at 18 hours. This difference may be related to differences in motivation between the two groups. The nonascending pike may have been sufficiently motivated to migrate upstream and remain in the area for some time after the obstacle of the fishway was encountered but not sufficiently motivated to attempt to ascend. Other pike that were more highly motivated were not delayed by this obstacle.

7.6 Migration

The recapture at the fishways in 1990 of three pike tagged in 1989 suggests that pike from a local population return to the area each year for spawning. However, captures of tagged fish from a variety of directions and at considerable distances from the study site suggest that pike in this area may have no distinct home range but travel freely throughout a broad area and use a number of spawning sites. This is supported by the capture of a pike tagged in 1989, during the 1990 spawning season, at Cross Lake, 45 kilometres from the study site.

7.7 Management Implications

7.7.1 Suitability of Standard Denil and Steeppass Fishways for Northern Pike

Efficiency comparisons in this study indicate that the steeppass fishway provides better passage for northern pike when operated at high flows. Since fishways generally operate with depths of flow at least as great as in the high flow in this study, the steeppass fishway would appear to be the most appropriate design for northern pike. However, pike were equally capable of ascending both fishways therefore the standard Denil design may also be appropriate for this species.

Only two efficiency estimates have been conducted for pool and weir fishways (Watters 1980, Minchau 1980) therefore comparisons to Denil fishways are difficult. As well, it is difficult to separate passage differences due to fishway type from differences due to entrance characteristics and competing attraction flows. However, it appears that both the steeppass and standard Denil fishways are better suited to northern pike than the pool and weir design.

No efficiency estimates are available for vertical slot fishways so direct comparisons cannot be made with this design.

7.7.2 Competing Attraction Flow

A major difference between the Siisiip fishways and other fishways was the absence of competing attraction flow from spillways or bypass channels. This may account for the higher efficiency and shorter delay times observed here.

The effects of competing attraction flow may be reduced by proper siting of the fishway entrance. The entrance should be at the point of maximum upstream movement of the fish and the velocity barrier of the spill pattern used to guide the fish to the entrance (Clay 1961, Pavlov 1989, Leman and Paulik 1966). In some situations, intermittent spills from the spillway may be used to advantage (Bell 1973, Pavlov 1989, Hayes 1953). Larger than normal discharges that will draw fish into the area, may alternate with periods of no discharge during which fish can more easily locate the fishway entrance. However, the alternating flooding and dewatering of downstream littoral areas may have adverse impacts on fish populations in these areas.

7.7.3 Swimming Ability of Northern Pike and Fishway Water Velocities

Burst swimming allows pike to quickly overcome the short stretches of high velocity water that are found in fishways. Pike in this study were capable of ascending fishways against water velocities between .50 and .78 m/sec.

These velocities are probably permissible in fishways used by pike. However, the observation of one pike being unable to ascend against a velocity of .47 m/sec suggests that such velocities may also be near the limit of pike capabilities. This has implications for fishway design since most Denil fishways operate with greater depths of flow and therefore higher water velocities. For example, velocities in the Denil fishway at the Fairford Dam ranged from 0.7 m/sec to 1.4 m/sec while velocities in the Cowan Dam fishway ranged between 0.7 m/sec and 1.7 m/sec (Katopodis et al. 1991). Such conditions, especially in long fishways, may restrict fish passage.

Water velocities in the Siisiip fishways did not appear to be prohibitive since a high rate of passage was observed. However, sixty per cent of pike did not ascend the fishways and the question arises as to whether prevailing water velocities prevented their ascent.

Pike could ascend the fishways by using various combinations of swimming speed and time. The speed versus time combinations for the standard Denil fishway operating at high flow (mean depth of .40 metres) are plotted as a curve in Figure 21. Two curves are presented, corresponding to the maximum and minimum velocities encountered in the fishway. Curves for the steeppass fishway would be very similar since water velocities were similar. The area between the two curves represents the combinations of time

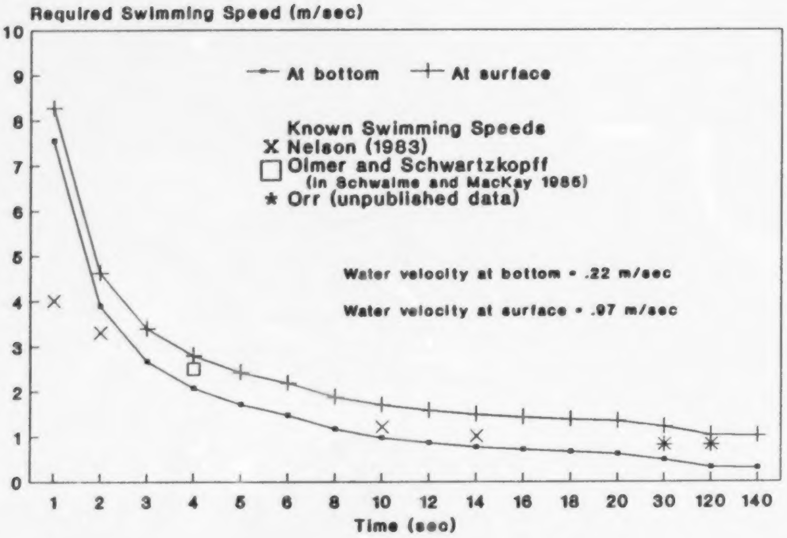


Figure 21. Velocity/time curves for standard Denil fishway operated at high flow (.40 m)

Note: Swimming speed = water velocity + forwardvelocity of fish.

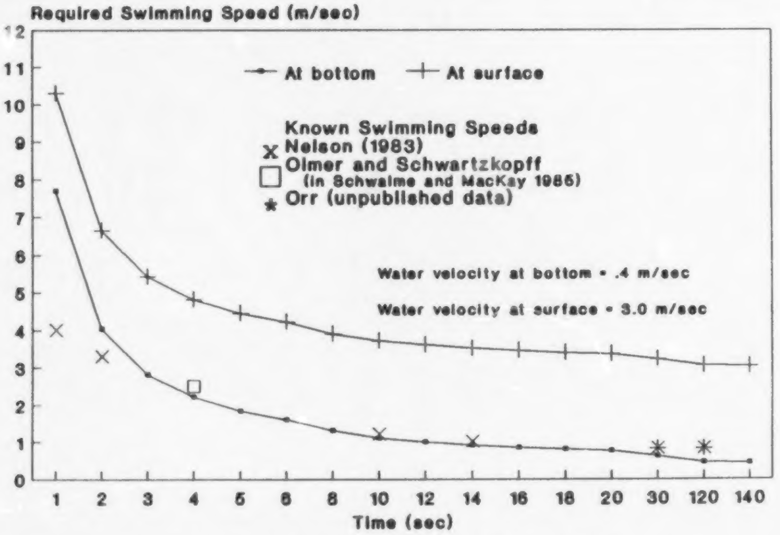


Figure 22. Velocity/time curves for standard Denil fishway operated with depth of flow of 1.4 metres.

Note: Swimming speed = water velocity + forwardvelocity of fish.

and swimming speed that would allow fishway ascent.

Known pike swimming speeds for various lengths of time are plotted as points in Figure 21. Comparison of these points to the curves indicates that for speed versus time combinations involving times of four seconds or longer, pike are capable of ascending the fishway. Thus, water velocities in the standard Denil fishway, operated at .40 metres depth, are not prohibitive to pike passage. However, all points representing pike swimming speed lie below the curve corresponding to the highest velocity in the fishway. This suggests that there are depth zones in the fishway with velocities that are excessive for pike.

The fishways in this study were built to operate at depths of flow up to 1.4 metres. This would result in higher water velocities and a greater challenge to migrating pike. Combinations of speed versus time required for pike ascent of the standard Denil fishway operated at 1.4 metres depth are plotted as curves in Figure 22. Two curves are presented, corresponding to the maximum and minimum velocities in the fishway. Known pike swimming speeds for various lengths of time are also plotted. Comparison of these points to the curves indicates that northern pike are capable of ascending the fishway for speed versus time combinations for the time range of four seconds and greater. However, these points lie very close to the lower curves suggesting that northern pike would be able to ascend only near the bottom in the standard Denil fishway.

Generalized velocity profiles are not available for steeppass fishways, therefore local water velocities cannot be accurately predicted. However, experimental studies (Rajaratnam and Katopodis 1991) show that the velocity profile of the steeppass fishway changes substantially at greater depths of flow. For y_o/b ratios greater than about 2.0, the maximum velocity occurs at mid-depth and lowest velocities occur at the surface and the floor of the fishway. The surface and bottom velocities tend to increase relative to those found at lower depths of flow. It would thus appear that only a small zone of passage would be available for ascent of northern pike in the steeppass fishway at an operating depth of 1.4 metres.

This analysis has been somewhat simplistic in that water velocity is the only force assumed to be acting on the fish. In addition to water velocity, pike ascending a fishway must also overcome virtual mass force and gradient force (Behlke et al. 1990). These additional forces may reduce pike swimming speeds in the fishway and further limit fishway performance.

A further complication may occur in Denil and steeppass fishways with more than one section. Burst swimming requires the use of white muscle tissue which functions anaerobically and incurs an oxygen deficit when used (Beamish 1978). Repayment of this oxygen debt takes time and swimming performance may decline if successive bouts of burst swimming are required over a short period. Pike may be capable of ascending single lengths of fishway as in this study but may be deterred by multiple lengths of fishway.

7.7.4 Motivation

Comparisons of the swimming ability of northern pike to prevailing water velocities in the Siisiip fishways indicate that pike are capable of ascending the fishways. However, not all pike reaching the fishway vicinity necessarily had sufficient motivation to enter and ascend the fishways. Migrational motivation is not as strong among freshwater fish as it is among anadromous fish (Collins and Gillis 1985). In particular, northern pike may lack sufficient motivation to overcome difficult obstacles to migration (Fernet 1984). Less than optimum fishway performance may be partly attributed to low motivation of pike.

7.7.5 Alternative Mitigation

Typically, mitigation for blockage of fish spawning runs by water control structures involves installation of fishways to allow further upstream passage of fish. With respect to northern pike, however, a fishway may not be the most appropriate mitigation. For various reasons, northern pike passage at fishways in western Canada has been poor. Further research may improve performance but attainment of a satisfactory level of performance may be difficult. Collins and Gillis (1985) suggest that 80% is the minimum acceptable passage rate for a fishway. Since this goal may not be achievable for northern pike, an alternative is creation of spawning areas downstream of the control structure. For example, extensive meadows below the Siisiip fishways could be developed into spawning marshes with controlled water levels to provide optimum conditions for pike reproduction.

8. Summary and Conclusions

Low water levels in 1989 prevented operation of the Siisiip fishways. Higher water levels in 1990 allowed proper fishway operation and performance comparisons were made between the standard Denil and steeppass fishways.

The fishways were operated simultaneously at two flow regimes. Low flow was characterized by mean depths of .25 m, discharges of about .045 m^3/sec, mean water velocities of .25 m/sec and maximum water velocities of .46 m/sec. The high flow regime had mean depths of .41 m, discharges of about .10 m^3/sec, mean water velocities of .41 m/sec and maximum water velocities of approximately .9 m/sec.

Eighty-seven pike, ranging in size from 25.2 cm (90 g) to 88.5 cm (5.8 kg), ascended the fishways during the study. Pike behaviour in choosing to ascend a particular fishway was probably governed by their reaction to different water velocities in combination with a characteristic approach path to the fishway entrances.

The first experiment showed that pike were equally capable of ascending both fishways under both low and high flow conditions. The second experiment showed that under high flow conditions, when characteristic flow patterns were present, pike preferred to use the steeppass fishway, probably due to a preference to swim against high water velocities. No difference in the use of fishways was observed at low flows.

During Experiment One, aggregate efficiency for pike was estimated at 4.7%. This is probably an underestimate of efficiency since fish behaviour was likely affected by the stress of capture in gill nets. During Experiment Two, fish were captured in traps, reducing stress on the fish. The aggregate efficiency in Experiment Two was estimated at a maximum of 38.7%. Passage efficiency was estimated at 32% for the steeppass fishway at high flow, 18% for the standard Denil fishway at low flow, 9% for the steeppass fishway at low flow and 4% for the standard Denil fishway at high flow. For the twelve hour operating periods, aggregate efficiency averaged 21.8%.

There were no differences in length, sex or spawning condition between pike ascending the two fishways. In comparing pike that ascended either fishway and pike that did not ascend the fishways, no differences were evident with respect to sex or spawning condition. However, ascending pike tended to be smaller than nonascending pike. The size difference was even greater when nonascending pike were compared to pike that ascended during high flow periods.

Limited observations suggest that pike swim in the higher velocity zones of the fishways. Timed ascents indicated swimming speeds between .61 m/sec and .87 m/sec over the length of the upper channel.

Pike arriving in the fishway vicinity were very quick to ascend the fishways. The median delay time was only 2.75 hours, considerably less than delay times of up to 16 days observed at other fishways. The short delay time is likely due to the absence of competing attraction flows in the area.

The steeppass fishway design appears to be preferred by northern pike when both fishways are available. However, the standard Denil design may be just as effective as the steeppass design if it is the only fishway available at a site. The high passage rates observed at this location may not be solely attributable to fishway design but may result from an absence of competing attraction flow.

Northern pike swimming abilities were sufficient to allow ascent of the fishways at the operating depths used in the study and should be sufficient to allow ascent at depths up to 1.4 metres. Pike may encounter difficulties in ascending standard Denil and steeppass fishways with greater depths.

In spite of a high passage rate relative to other fishways, about 60% of the pike still did not ascend the fishways. This suggests that the steeppass design may not be ideal for pike and other designs should be tested. Also, pike motivation may be insufficient for total passage at any facility and alternative mitigation to fishways may need to be considered where pike migrations are blocked.

9. Recommendations

9.1 Management Recommendations

1. For planned fishway installations where northern pike is the major species of concern, either the steeppass or the standard Denil design may be used. Further research is required before either design can be regarded as superior for pike.
2. In planning mitigation for blockage of fish spawning runs involving substantial numbers of northern pike, alternative mitigation should be considered. For northern pike, an appropriate alternative may be development of spawning marshes immediately downstream of the barrier. Alternatives such as this may be developed as the sole mitigation or in conjunction with a fishway.
3. New fishway structures should be installed to allow easy removal and replacement with other

fishway types if monitoring shows poor fish passage. Ideally, designs should allow for side-by-side installation of two fishways for comparative purposes.

9.2 Research Recommendations

1. Further comparisons of the standard Denil and steeppass fishways should be conducted at another site with larger numbers of fish to corroborate the results of this study and to determine the suitability of each design for other species such as walleye.
2. A similar comparative study should be conducted with steeppass and vertical slot fishways.
3. The present study indicated more pike ascents at greater operating depths (ie. greater discharge and velocity). Greater operating depths than used in this study may stimulate higher rates of passage. Further research should be conducted to determine the operating depth and water velocity that results in the best passage of northern pike.
4. Absence of competing attraction flow may be one reason why the passage rate of pike was relatively high in this study. Research should be conducted at a fishway situated adjacent to a spillway to determine if fishway passage differs during time

periods with and without spillway flow.

5. Research is needed on pike swimming abilities. Very little information is presently available on pike swimming speeds over time periods of ten to thirty seconds which is the time span needed for ascent of a single section of Denil fishway.
6. Research should be conducted to determine the ability of pike to undergo successive bouts of burst swimming such as is required to ascend Denil fishways of several sections.

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Appendix 1. Derivation of discharge and velocity values for Siisiip fishways.

1) Discharge Q

a) Standard Denil fishway

$Q* = Q/\sqrt{gS_o b_o^5}$ and, $g = 9.81$ m/sec^2

$S_o = .1$

$Q* = 0.94(y_o/b_o)^2$ therefore, $b_o = .406$ m

$Q/\sqrt{gS_o b_o^5} = 0.94(y_o/b_o)^2$ and

$Q = 0.098(y_o/b_o)^2$

Q is found by substituting .406 m for b_o and the measured depth for y_o and solving.

b) Steeppass fishway

$Q* = Q/\sqrt{gS_o b_o^5}$ and, $g = 9.81$ m/sec^2

$S_o = .1$

$Q* = 0.97(y_o/b_o)^{1.55}$ therefore, $b_o = .406$ m

$Q/\sqrt{gS_o b_o^5} = 0.97(y_o/b_o)^{1.55}$ and

$Q = .101(y_o/b_o)^{1.55}$

Q is found by substituting .406 m for b_o and the measured depth for y_o and solving.

2) Calculation of local velocities

a) Standard Denil fishway

Dimensionless discharge curves were used to calculate Q* based on y_o/b_o:

$Q* = 0.94(y_o/b_o)^2$

Dimensionless velocity scales were used to calculate the velocity scale u'm based on Q*:

$U* = 0.76\ Q*^{0.61} = u'_m / \sqrt{gS_o b_o}$

Local centreline velocities were then calculated using the following equations:

Where $0.6 < y_o/b < 0.9$,

$$u/u'_m = 0.58 + 0.33(y/y_o) - 1.78(y/y_o)^2 + 2.80(y/y_o)^3$$

Where $0.9 < y_o/b < 1.2$,

$$u/u'_m = 0.40 + 0.98(y/y_o) - 3.45(y/y_o) + 4.32(y/y_o)^3$$

b) Steeppass fishway

Dimensionless discharge curves were used to calculate Q^* based on y_o/b_o:

$$Q^* = 0.97(y_o/b_o)^{1.55}$$

Dimensionless velocity scales were used to calculate the velocity scale u_m based on Q^*:

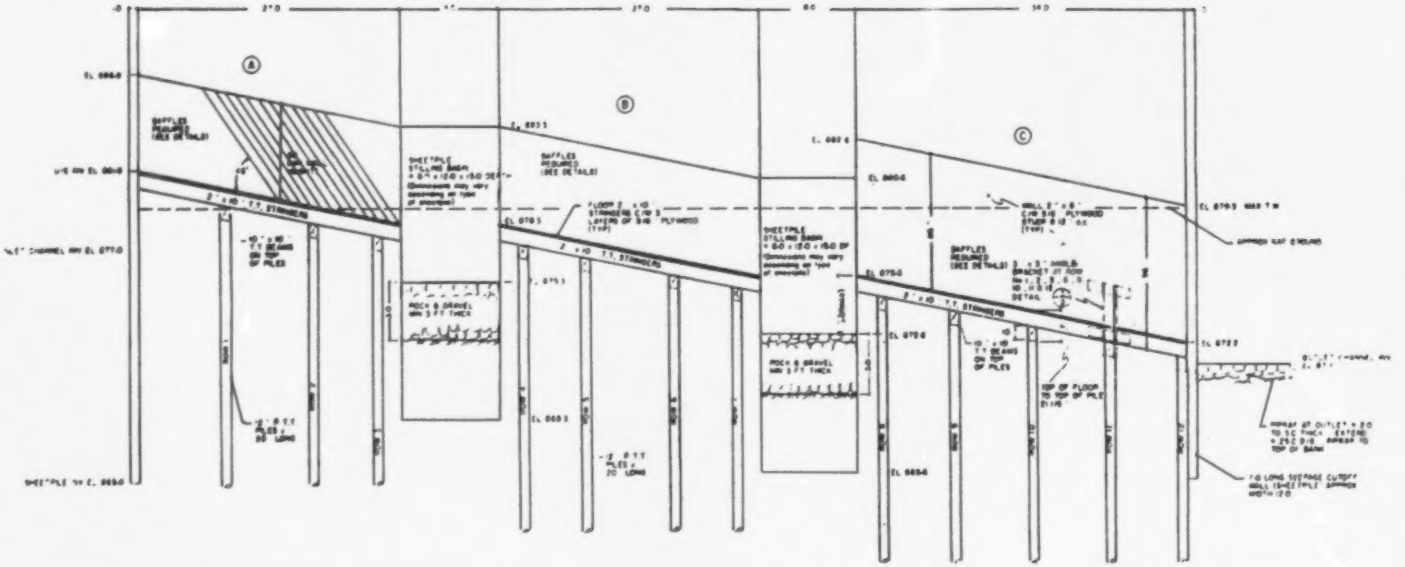
$$U^* = 1.43\ Q^{*0.48} = u_m \ / \sqrt{g S_o b_o}$$

Local centreline velocities were then calculated using the following equation:

$$u/u_m = 1.067e^{-1.878(y/yo)}$$

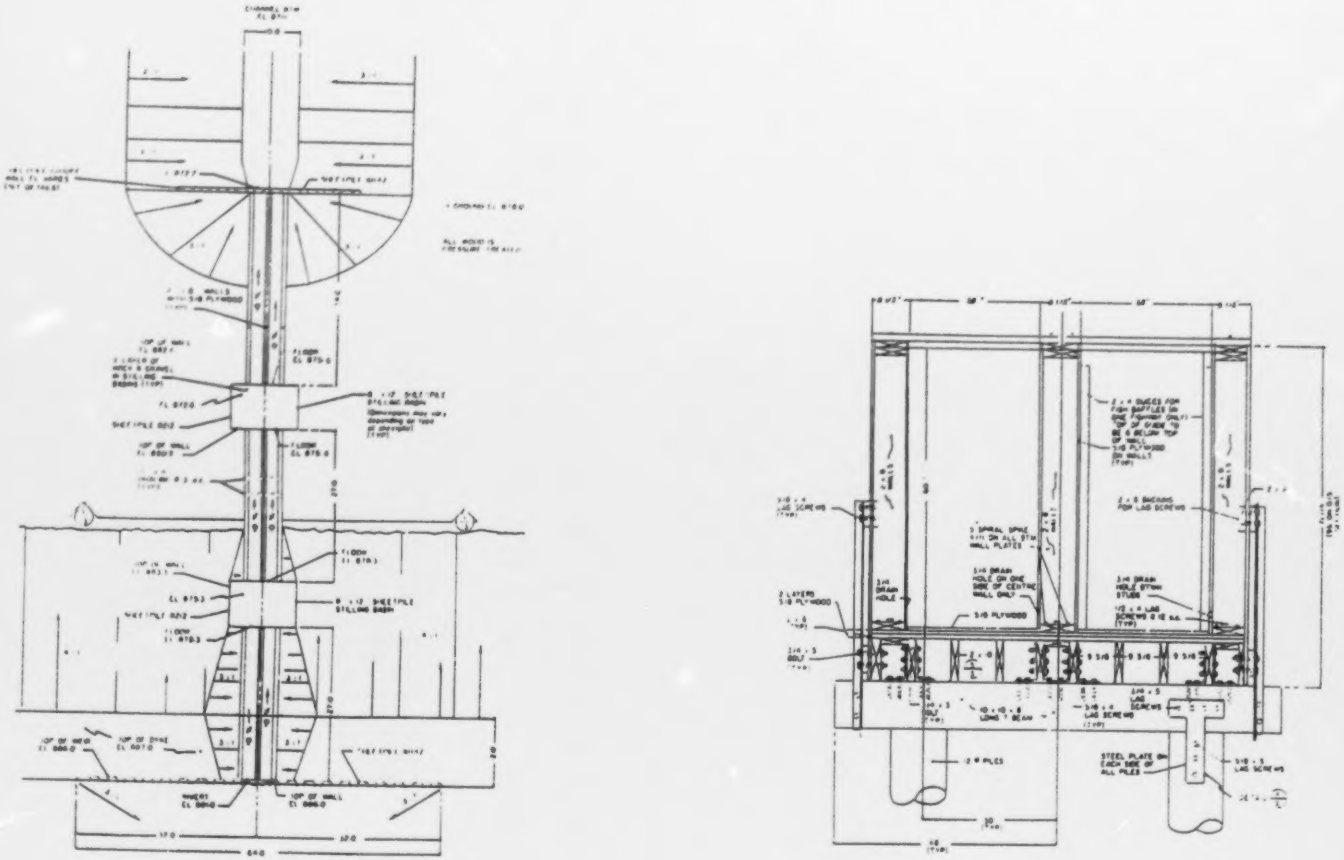
3) Calculation of average velocities U

For both fishways, the depth-averaged velocity U for each time period was calculated as the arithmetic mean of the local velocities u.

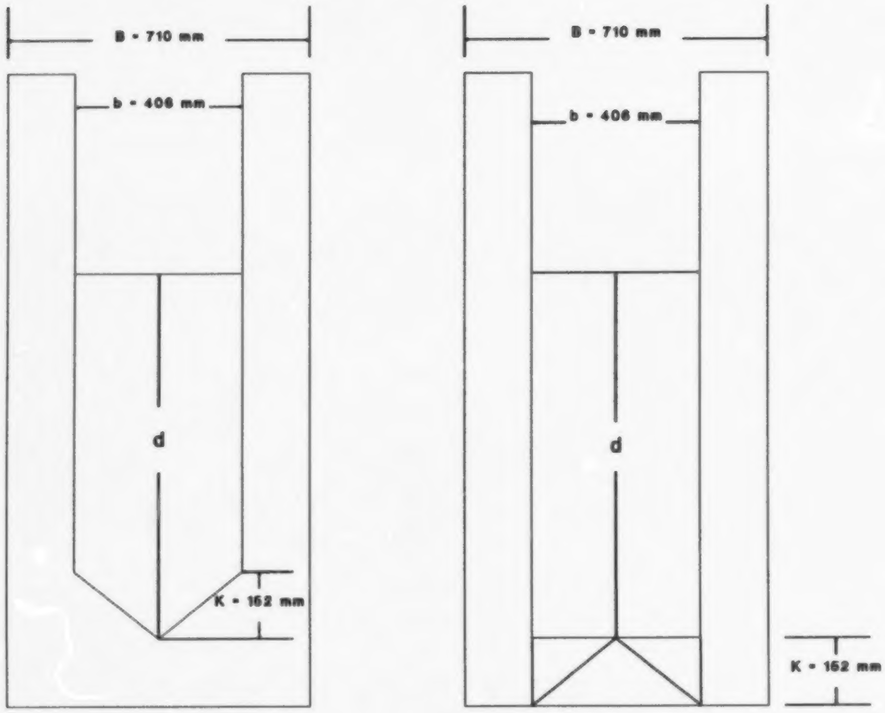


27.0
27.0
8.0
34.0
A
B
C
BAFFLES REQUIRED (SEE DETAILS)
BAFFLES REQUIRED (SEE DETAILS)
BAFFLES REQUIRED (SEE DETAILS)
SHEETPILE STILLING BASIN
SHEETPILE STILLING BASIN
ROCK & GRAVEL MIN 3 FT THICK
ROCK & GRAVEL MIN 3 FT THICK
T.T. STRINGERS
T.T. STRINGERS
T.T. STRINGERS
T.T. BEAMS ON TOP OF PILES
T.T. BEAMS ON TOP OF PILES
BAFFLES REQUIRED (SEE DETAILS)
TOP OF FLOOR TO TOP OF PILE
APPROX NAT GROUND

Appendix 2. Plan of Siisiip fishways, elevation view (unspecified dimensions in feet)


8 x 12 SHEETPILE STILLING BASIN
SHEETPILE WALL
TOP OF WALL
10.0
32.0
64.0
2 x 4 GUIDES FOR FISH BAFFLES ON ONE FISHWAY ONLY TOP OF GUIDE TO BE 6 BELOW TOP OF WALL
5/8 PLYWOOD ON WALLS (TYP)
2 x 6 BACKING FOR LAG SCREWS
3/4 DRAIN HOLE ON ONE SIDE OF CENTRE WALL ONLY
3/4 DRAIN HOLE
2 LAYERS 5/8 PLYWOOD
5/8 PLYWOOD
3/4 DRAIN HOLE BTWN STUDS
1/2 x 4 LAG SCREWS @ 12 o.c. (TYP)
5/8 x 3 BOLT (TYP)
5/8 x 4 LAG SCREWS (TYP)
5/8 x 5 LAG SCREWS
LONG T BEAM
STEEL PLATE ON EACH SIDE OF ALL PILES
10 (TYP)
48 (TYP)

Appendix 2 (cont'd). Plan of Siisiip fishways. Left - plan view, right - cross-section (unspecified dimensions in feet)



Standard Denil

Steeppass

Appendix 3. Dimensions of baffles used in Siisiip fishways.

Appendix 4. Details of northern pike ascents of the standard Denil fishway during experimental trials in 1989.

The standard Denil fishway was modified by placing boards at the upper end of the middle channel to raise the water level in the upper resting pool by approximately 10 centimeters. This eliminated the water fall effect at the lower end of the upper channel. A screen was placed at the upper end of the middle channel to prevent downstream escape of pike.

Pike captured in the downstream trap were then placed in the upper resting pool in groups and their movements observed.

Group One - May 9, 1989

Tag #	Length (cm)	Sex	Spawning Condition	Observations
1109	56.4	M	E	Ascended to exit
1111	67.2	F	R	Ascended to exit
1052	58.8	F	R	Ascended to exit

Group Two - May 10, 1989

Tag #	Length (cm)	Sex	Spawning Condition	Observations
1112	45.8	M	E	Did not ascend
1113	57.2	F	S	Did not ascend
1115	54.0	M	E	Ascended to exit after three hours
1116	56.2	M	E	Did not ascend
1117	62.0	F	G	Did not ascend

Group Three - May 11, 1989

Tag #	Length (cm)	Sex	Spawning Condition	Observations
1120	48.8	M	E	Did not ascend
1127	56.0	M	S	Ascended to exit after eight hours
1128	59.0	M	E	Did not ascend
1129,1130	76.8	F	S	Ascended to exit after three hours
7005	39.8	M	E	Ascended to exit after seven hours

Appendix 4, continued. Details of northern pike ascents of the standard Denil fishway during experimental trials in 1989.

On May 12, modifications were made to the baffles to allow continuous movement of fish from the lower resting pool to the exit of the standard Denil fishway. A screen was placed at the upper end of the lower fishway channel to prevent escape. Two groups of fish were placed in the lower resting pool and their movements observed.

Group Four - May 12, 1989

Tag #	Length (cm)	Sex	Spawning Condition	Observations
1135	59.0		S	Ascended to upper pool after 30 minutes. Ascended to exit after one hour, thirty minutes.
1136	65.6		S	Ascended to upper pool after 30 minutes. Did not ascend to exit.
1140	67.2	M	R	Did not ascend.
1143	70.4	M	E	Did not ascend.
1144	47.2		S	Ascended to upper pool after 30 minutes. Ascended to exit after one hour.

Appendix 4, continued. Details of northern pike ascents of the standard Denil fishway during experimental trials in 1989.

Group Five - May 13, 1989

Tag #	Length (cm)	Sex	Spawning Condition	Observations
(Pike)				
1133	50.8	M	S	Ascended to exit after 45 minutes.
1138	53.8		S	Ascended to exit after 35 minutes.
1139	63.8	M	E	Ascended to upper pool after ten minutes. Ascended to exit after one hour.
1141	66.0	F	R	Ascended to exit one hour,thirty-five minutes.
7023	41.2	M	E	Ascended to exit after thirty-five minutes.
(White sucker)				
1149	39.6	M	E	Did not ascend.
1176	42.0	F	S	Ascended to upper pool after one hour ten minutes.

Appendix 5. Tagged white suckers and northern redhorse suckers, Siisiip fishways, 1989.

Tag Number	Species	Capture Location	Date	Time	Fork Length (cm)	Weight (g)	Sex	Reproductive Condition	Release Location
1059	W Sucker	us trap	5/ 5/1989	1230 PM	45			S	pool
1110	W Sucker	us trap	5/ 9/1989	905 AM	46			S	pool
1121	N R Sucker	us trap	5/11/1989	900 AM	38	750			pool
1149	W Sucker	us trap	5/13/1989	905 AM	40	1075	M	E	pool
1176	W Sucker	us trap	5/13/1989	915 AM	42	1325	F	S	pool
1177	W Sucker	us trap	5/15/1989	900 AM	48	1500		S	pool
1178	W Sucker	ds trap	5/15/1989	730 PM	47	1400	M	S	acc chan
1181	W Sucker	ds trap	5/16/1989	800 PM	43		F	R	acc chan
1185	W Sucker	gill net	5/16/1989		45		M	R	
1183	W Sucker	gill net	5/16/1989		44		M	S	
1184	W Sucker	gill net	5/16/1989		40		M	S	
1182	W Sucker	gill net	5/16/1989		40		M	S	
1186	W Sucker	gill net	5/16/1989		42		M	S	

Appendix 6. Tagging data for white suckers, Siisiip fishways, 1990. (Records arranged chronologically)

Note: TDS denotes fish that were initially captured and tagged at the downstream trap.

Tag Number	Capture Location	Date	Time	Fork Length (cm)	Weight (g)	Sex	Reproductive Condition	Release Location
7078	gill net	5/11/1990	100 PM	42	425		S	pool
1413	gill net	5/12/1990	1130 AM	44	1125	M	R	pool
1416	ds trap	5/14/1990	1000 AM	42	1350		S	acc chan
1417	ds trap	5/14/1990	1000 AM	42	1150		S	acc chan
7308	us trap	5/17/1990	1000 AM	49	1525	F	S	pool
7312	us trap	5/17/1990	1000 AM	45	1400	F	S	pool
7311	us trap	5/17/1990	1000 AM	43	1200	F	S	pool
7313	us trap	5/17/1990	1000 AM	47	1400	F	S	sacrificed
7315	us trap	5/17/1990	1000 AM	44	1175	M	S	pool
7314	us trap	5/17/1990	1000 AM	47	1450	F	S	pool
7300	us trap	5/17/1990	1000 AM	46	1450	F	S	pool
7299	us trap	5/17/1990	1000 AM	47	1525	F	S	pool
7310	us trap	5/17/1990	1000 AM	48		F	S	sacrificed
7305	us trap	5/17/1990	1000 AM	50	1900	F	S	pool
7304	us trap	5/17/1990	1000 AM	49	1800	F	S	pool
7303	us trap	5/17/1990	1000 AM	45	1175	F	S	pool
7266	ds trap	5/17/1990	1030 AM					acc chan
7314	ds trap	5/17/1990	1030 AM					acc chan
7254	us trap	5/17/1990	900 AM	47	1375	M	S	pool
7260	us trap	5/17/1990	900 AM	49	1550	M	S	pool
7265	us trap	5/17/1990	930 AM	48	1475	F	S	pool
7286	us trap	5/17/1990	930 AM	42	1100	M	R	pool
7261	us trap	5/17/1990	930 AM	47	1650	F	S	pool
7292	us trap	5/17/1990	930 AM	52	2200	F	S	pool
7266	us trap	5/17/1990	930 AM	45	1275	F	S	pool
7293	us trap	5/17/1990	930 AM	49	1675	F	S	pool
7291	us trap	5/17/1990	930 AM	46	1600	F	S	pool
7262	us trap	5/17/1990	930 AM	49	1700	F	S	pool
7290	us trap	5/17/1990	930 AM	50	1700	F	S	pool
7267	us trap	5/17/1990	930 AM	44	1175	F	S	pool
7294	us trap	5/17/1990	930 AM	51	1650	F	S	pool
7264	us trap	5/17/1990	930 AM	47	1550	F	S	pool
7263	us trap	5/17/1990	930 AM	48	1650	F	S	pool
7298	us trap	5/17/1990	930 AM	50	1900	F	S	pool
7361	ds trap	5/18/1990	800 PM				S	acc chan
7362	ds trap	5/18/1990	800 PM				S	acc chan
7254	ds trap	5/18/1990	800 PM				S	acc chan
7331	ds trap	5/18/1990	800 PM				S	acc chan
7357	ds trap	5/18/1990	800 PM				S	acc chan
7375	ds trap	5/18/1990	800 PM				S	acc chan

7329	us trap	5/18/1990	830 AM	46	1325	F	S	pool
7331	us trap	5/18/1990	830 AM	50	1800	F	S	pool
7336	us trap	5/18/1990	830 AM	50	1875	F	S	pool
7328	us trap	5/18/1990	830 AM	47	1575	F	S	pool
7361	us trap	5/18/1990	900 AM	49	1650	F	S	pool
7362	us trap	5/18/1990	900 AM	48	1675	M	S	pool
7375	us trap	5/18/1990	900 AM	46	1450	F	S	pool
7359	us trap	5/18/1990	900 AM	43	1050	M	S	pool
7358	us trap	5/18/1990	900 AM	49	1500	M	S	pool
7356	us trap	5/18/1990	900 AM	52	2050	F	S	pool
7355	us trap	5/18/1990	900 AM	46	1450	F	S	pool
7353	us trap	5/18/1990	900 AM	49	1900	F	S	pool
7357	us trap	5/18/1990	900 AM	47	1425	F	S	pool
7328	ds trap	5/18/1990	930 AM				S	acc chan
7356	ds trap	5/18/1990	930 AM				S	acc chan
7263	ds trap	5/18/1990	930 AM				S	acc chan
7308	ds trap	5/18/1990	930 AM				S	acc chan
7312	ds trap	5/18/1990	930 AM				S	acc chan
7294	ds trap	5/18/1990	930 AM				S	acc chan
7292	ds trap	5/18/1990	930 AM				S	acc chan
7293	ds trap	5/18/1990	930 AM				S	acc chan
7267	ds trap	5/18/1990	930 AM				S	acc chan
7290	ds trap	5/18/1990	930 AM				S	acc chan
7298	ds trap	5/18/1990	930 AM				S	acc chan
7265	ds trap	5/18/1990	930 AM				S	acc chan
7305	ds trap	5/18/1990	930 AM				S	acc chan
7260	ds trap	5/18/1990	930 AM				S	acc chan
7264	ds trap	5/18/1990	930 AM				S	acc chan
7303	ds trap	5/18/1990	930 AM				S	acc chan
7262	ds trap	5/18/1990	930 AM				S	acc chan
7366	us trap	5/19/1990	830 AM	49	1675	F	S	pool
7370TDS	ds trap	5/19/1990	900 AM	47	1675	F	S	acc chan
7355	ds trap	5/19/1990	900 AM				S	acc chan
7358	ds trap	5/19/1990	900 AM				S	sacrificed
7368TDS	ds trap	5/19/1990	900 AM	48	1675	F	S	acc chan
7369TDS	ds trap	5/19/1990	900 AM	48	1700	F	S	acc chan
7336	ds trap	5/19/1990	900 AM				S	acc chan
7353	ds trap	5/19/1990	900 AM				S	acc chan
7366	ds trap	5/20/1990	1015 AM				S	acc chan
7378TDS	ds trap	5/20/1990	1015 AM	46	1575	M	S	acc chan
7379TDS	ds trap	5/20/1990	1015 AM	46	1525			acc chan
7381	gill net	5/20/1990	1045 AM	46	1475	F	S	acc chan
7380	gill net	5/20/1990	1045 AM	46	1400	F	S	acc chan

Appendix 7. Tagging data for northern pike, Siisiip fishways, 1989.
(Records arranged chronologically)

( ) - signifies a tag originally applied but later removed or lost
[ ] - signifies a tag applied in the previous year
Two numbers separated by a comma signifies two tags applied to same fish
TAC signifies that the fish was tagged at the fishway exit
TDS signifies that the fish was tagged at the downstream trap

Tag Number	Capture Location	Date	Time	Fork Length (cm)	Weight (g)	Sex	Reproductive Condition	Release Location
1003	us trap	5/ 4/1989	940 AM	57		M	E	pool
1004	us trap	5/ 4/1989	940 AM	55		M	G	pool
1006	us trap	5/ 4/1989	940 AM	59		M	E	pool
1008	us trap	5/ 4/1989	940 AM	57		F	S	pool
1009	us trap	5/ 4/1989	940 AM	56		M	E	pool
1011	us trap	5/ 4/1989	940 AM	67		F	R	pool
1012	us trap	5/ 4/1989	1000 AM	52		M	E	retnr
1014	us trap	5/ 4/1989	1000 AM	64		F	E	retnr
1017	us trap	5/ 4/1989	1000 AM	78		M	E	retnr
1019	us trap	5/ 4/1989	1000 AM	51		F	E	retnr
1020	us trap	5/ 4/1989	1000 AM	61		F	E	retnr
1022	us trap	5/ 4/1989	1000 AM	52		F	E	retnr
7002	us trap	5/ 4/1989	1000 AM	42		M	E	retnr
1007	us trap	5/ 4/1989	1000 AM	52		F	E	retnr
1012	retnr	5/ 5/1989	1130 AM	52		M	E	pool
1014	retnr	5/ 5/1989	700 AM	64		F	E	pool
1017	retnr	5/ 5/1989	700 AM	78		M	E	pool
1019	retnr	5/ 5/1989	700 AM	51		F	E	pool
1020	retnr	5/ 5/1989	700 AM	61		F	E	pool
1022(1073)	retnr	5/ 5/1989	700 AM	52		F	E	pool
7002	retnr	5/ 5/1989	700 AM	42		M	E	pool
1007	retnr	5/ 5/1989	700 AM	52		F	E	pool
1026	us trap	5/ 5/1989	1140 AM	55			S	pool
1027	us trap	5/ 5/1989	1140 AM	51		M	S	pool
1028	us trap	5/ 5/1989	1140 AM	61		F	G	pool
1029	us trap	5/ 5/1989	1140 AM	52		M	E	pool
1031	us trap	5/ 5/1989	1140 AM	52		M	E	pool
1032	us trap	5/ 5/1989	1140 AM	50		M	E	pool
1033	us trap	5/ 5/1989	1140 AM	51		M	E	pool
1035	us trap	5/ 5/1989	1140 AM	47		M	E	pool
1036	us trap	5/ 5/1989	1200 PM	46		M	E	pool
1037	us trap	5/ 5/1989	1200 PM	55		M	E	pool
1038	us trap	5/ 5/1989	1200 PM	58		M	E	pool
1039	us trap	5/ 5/1989	1200 PM	61		M	E	pool
1040	us trap	5/ 5/1989	1200 PM	58		M	E	pool
1041	us trap	5/ 5/1989	1200 PM	51		F	E	pool
1042	us trap	5/ 5/1989	1200 PM	52		M	E	pool

1043	us trap	5/ 5/1989	1200 PM	53	M	E	pool
1044	us trap	5/ 5/1989	1220 PM	62	F	G	pool
1045	us trap	5/ 5/1989	1220 PM	51	M	E	pool
1046	us trap	5/ 5/1989	1220 PM	51	M	E	pool
1047	us trap	5/ 5/1989	1220 PM	59	M	E	pool
1048	us trap	5/ 5/1989	1220 PM	57	M	G	pool
1049	us trap	5/ 5/1989	1220 PM	62	M	E	pool
1050	us trap	5/ 5/1989	1220 PM	56	F	G	pool
1051	us trap	5/ 5/1989	1220 PM	51		G	pool
1052	us trap	5/ 5/1989	1240 PM	59	F	R	pool
1053	us trap	5/ 5/1989	1240 PM	62	M	E	pool
1054	us trap	5/ 5/1989	1240 PM	48	M	E	pool
1055	us trap	5/ 5/1989	1240 PM	52	M	E	pool
1056(1074)	us trap	5/ 5/1989	1240 PM	55	M	E	pool
1057	us trap	5/ 5/1989	1240 PM	50	M	E	pool
1058	us trap	5/ 5/1989	1240 PM	60		G	pool
1064	ds trap	5/ 5/1989	1000 PM	93	F	R	pool
1061	ds trap	5/ 5/1989	1000 PM	102	F	R	pool
1062	ds trap	5/ 5/1989	1000 PM	82	F	R	pool
1063,1066	ds trap	5/ 5/1989	1000 PM	91	F	R	pool
1018	ds trap	5/ 5/1989	500 PM				channel
1008	ds trap	5/ 5/1989	500 PM	57	F	S	channel
1053	ds trap	5/ 5/1989	500 PM	62	M	E	channel
1052	ds trap	5/ 5/1989	500 PM	59	F	R	channel
1027	ds trap	5/ 5/1989	520 PM	51	M	S	channel
1007	ds trap	5/ 5/1989	520 PM	52	F	E	channel
1004	ds trap	5/ 5/1989	520 PM	55	M	G	channel
1026	ds trap	5/ 5/1989	520 PM	55		S	channel
1058	ds trap	5/ 5/1989	520 PM	60		G	channel
1057	ds trap	5/ 5/1989	520 PM	50	M	E	channel
1003	ds trap	5/ 5/1989	520 PM	57	M	E	channel
1040	ds trap	5/ 5/1989	520 PM	58	M	E	channel
1037	ds trap	5/ 5/1989	520 PM	55	M	E	channel
1041	ds trap	5/ 5/1989	540 PM	51	F	E	channel
1019	ds trap	5/ 5/1989	540 PM	51	F	E	channel
1042	ds trap	5/ 5/1989	540 PM	52	M	E	channel
1047	ds trap	5/ 5/1989	540 PM	59	M	E	channel
1046	ds trap	5/ 5/1989	540 PM	51	M	R	channel
1020	ds trap	5/ 5/1989	540 PM	61	F	E	channel
1031	ds trap	5/ 5/1989	540 PM	52	M	E	channel
7002	ds trap	5/ 5/1989	540 PM	42	M	E	channel
1036	ds trap	5/ 5/1989	540 PM	46	M	E	channel
1062	ds trap	5/ 5/1989	600 PM	82	F	R	channel
1017	ds trap	5/ 5/1989	600 PM	78	M	E	channel
1028	ds trap	5/ 5/1989	600 PM	61	F	G	channel
1012	ds trap	5/ 5/1989	600 PM	52	M	E	channel
1033	ds trap	5/ 5/1989	600 PM	51	M	E	channel
1014	ds trap	5/ 5/1989	600 PM	64	F	E	channel
1045	ds trap	5/ 5/1989	600 PM	51	M	E	channel
1051	ds trap	5/ 5/1989	600 PM	51		G	channel

1006	ds trap	5/ 5/1989	600 PM	59		M	E	channel
1061	ds trap	5/ 5/1989	620 PM	102		F	R	channel
1064	ds trap	5/ 5/1989	620 PM	93		F	R	channel
1022(1073)	ds trap	5/ 5/1989	620 PM	52		F	E	channel
1056(1074)	ds trap	5/ 5/1989	620 PM	55		M	E	channel
1076	ds trap	5/ 5/1989	640 PM	50		M	G	channel
1071	ds trap	5/ 5/1989	640 PM	46		M	G	channel
1072	ds trap	5/ 5/1989	640 PM	55		M	E	channel
1075	ds trap	5/ 5/1989	640 PM	52		F	R	channel
1019	us trap	5/ 7/1989	1040 AM	51		F	R	pool
1077	us trap	5/ 7/1989	1040 AM	52	950	M	E	pool
1052	us trap	5/ 7/1989	1040 AM	59		F	R	pool
1078	us trap	5/ 7/1989	1040 AM	47	775	M	E	pool
1079	us trap	5/ 7/1989	1040 AM	53	825	F	R	pool
1080	us trap	5/ 7/1989	1040 AM	57	1450	M	E	pool
1081	us trap	5/ 7/1989	1040 AM	67	2200	M	E	pool
1028	us trap	5/ 7/1989	1040 AM	61		F	G	pool
1033	us trap	5/ 7/1989	1040 AM	51		M	E	pool
1055,1085	us trap	5/ 7/1989	1040 AM	52		M	S	pool
1083	us trap	5/ 7/1989	1040 AM	53	1000	M	S	pool
1084	us trap	5/ 7/1989	1040 AM	52	950	F	R	pool
1086	us trap	5/ 7/1989	1100 AM	66	1800	F	R	pool
1087	us trap	5/ 7/1989	1100 AM	64	1875	M	E	pool
1071	us trap	5/ 7/1989	1100 AM	46		M	G	pool
1088	us trap	5/ 7/1989	1100 AM	51	1000	M	E	pool
1089	us trap	5/ 7/1989	1100 AM	56	1350	M	E	pool
1090	us trap	5/ 7/1989	1100 AM	67	2400	F	E	pool
1091	us trap	5/ 7/1989	1120 AM	78	3500	M	E	pool
1040	us trap	5/ 7/1989	1120 AM	58		M	E	pool
1062	us trap	5/ 7/1989	1120 AM	82		F	R	pool
1061	us trap	5/ 7/1989	1120 AM	102		F	R	pool
1060	us trap	5/ 7/1989	1140 AM			F	R	pool
1050	ds trap	5/ 7/1989	200 PM	56		F	R	channel
1075	ds trap	5/ 7/1989	200 PM	52		F	R	channel
1092	ds trap	5/ 7/1989	200 PM	47	750	F	E	channel
1093	ds trap	5/ 7/1989	200 PM	51	850	M	E	channel
1033	ds trap	5/ 7/1989	200 PM	51		M	E	channel
1078	ds trap	5/ 7/1989	200 PM	47	775	M	E	channel
1094	ds trap	5/ 7/1989	220 PM	58	1275	M	E	channel
1095	ds trap	5/ 7/1989	220 PM	56	1350	M	E	channel
1096	ds trap	5/ 7/1989	220 PM	51	1000		G	channel
1097,1098	ds trap	5/ 7/1989	220 PM	94		F	R	channel
1099	ds trap	5/ 7/1989	220 PM	55	1175	M	R	channel
1079	ds trap	5/ 7/1989	240 PM	53	825	F	R	channel
1032	ds trap	5/ 7/1989	240 PM	50		M	E	channel
1100	ds trap	5/ 7/1989	240 PM	51	1000	M	E	channel
1101	ds trap	5/ 7/1989	240 PM	55	1100	M	E	channel
1102	ds trap	5/ 7/1989	240 PM	49	750	M	E	channel
1103	ds trap	5/ 7/1989	300 PM	51	975	M	E	channel
1061	ds trap	5/ 7/1989	300 PM	102		F	R	channel

1060	ds trap	5/ 7/1989	300 PM			F	R	channel
1054	ds trap	5/ 7/1989	300 PM	48		M	E	channel
1029	ds trap	5/ 7/1989	300 PM	52		M	S	channel
1049	ds trap	5/ 7/1989	300 PM	62		M	E	channel
1104	ds trap	5/ 7/1989	300 PM	53	1025	F	R	channel
1044	ds trap	5/ 7/1989	300 PM	62		F	E	channel
7024	ds trap	5/ 7/1989	300 PM	42	475	M	E	channel
1062	ds trap	5/ 7/1989	300 PM	82		F	R	channel
1011(1068)	ds trap	5/ 7/1989	320 PM	67	2100	F	R	channel
1089	ds trap	5/ 8/1989	940 AM	56	1350	M	E	channel
1091	ds trap	5/ 8/1989	940 PM	78	3500	M	E	channel
1032	ds trap	5/ 8/1989	940 AM	50		M	S	channel
1058	ds trap	5/ 8/1989	940 PM	60			G	channel
1106	ds trap	5/ 8/1989	940 PM	73	3200	F	E	channel
1090	ds trap	5/ 8/1989	940 PM	67	2400	F	R	channel
1071	ds trap	5/ 8/1989	940 PM	46		M	E	channel
1019	ds trap	5/ 8/1989	940 PM	51		F	R	channel
1084	ds trap	5/ 8/1989	940 PM	52	950	F	R	channel
1055,1085	ds trap	5/ 8/1989	940 PM	52			S	channel
1080	ds trap	5/ 8/1989	1000 AM	57	1450	M	E	channel
1035	ds trap	5/ 8/1989	1000 AM	47		M	S	channel
1083	ds trap	5/ 8/1989	1000 AM	53	1000	M	S	channel
1107	ds trap	5/ 8/1989	1000 AM	46	650	M	E	channel
1028	ds trap	5/ 8/1989	1000 AM	61		F	E	channel
1087	ds trap	5/ 8/1989	1000 AM	64	1875	M	E	channel
1052	ds trap	5/ 8/1989	1000 AM	59		F	R	channel
1040	ds trap	5/ 8/1989	1000 AM	58		M	E	channel
1063,1066	ds trap	5/ 8/1989	1000 AM	91		F		channel
1038	ds trap	5/ 8/1989	1015 AM	58		M	E	channel
1108	us trap	5/ 9/1989	900 AM	49		F	S	retnr
1052	us trap	5/ 9/1989	900 AM	59		F	R	retnr
1109	us trap	5/ 9/1989	900 AM	55		M	E	retnr
1111	us trap	5/ 9/1989	900 AM	53		M	E	retnr
1077	ds trap	5/ 9/1989	930 AM	52	950	M	S	channel
1108	retnr	5/ 9/1989	100 PM	49		F	S	pool
1052	retnr	5/ 9/1989	100 PM	59		F	R	pool
1109	retnr	5/ 9/1989	100 PM	55		M	E	pool
1111	retnr	5/ 9/1989	100 PM	53		M	E	pool
1112	us trap	5/10/1989	1000 AM	46	600	M	E	retnr
1113	us trap	5/10/1989	1000 AM	57	1125	F	S	retnr
1114	us trap	5/10/1989	1000 AM	47	750	M	E	retnr
1115	us trap	5/10/1989	1000 PM	54	1150	M	E	retnr
1116	us trap	5/10/1989	1000 AM	56	1350	M	E	retnr
1117	us trap	5/10/1989	1000 AM	62	1675	F	G	retnr
1112	retnr	5/10/1989	500 PM	46	600	M	E	pool
1113	retnr	5/10/1989	500 PM	57	1125	F	S	pool
1114	retnr	5/10/1989	500 PM	47	750	M	E	pool
1115	retnr	5/10/1989	500 PM	54	1150	M	E	pool
1116	retnr	5/10/1989	500 PM	56	1350	M	E	pool
1117	retnr	5/10/1989	500 PM	62	1675	F	G	pool

7004	ds trap	5/10/1989	1030 AM			M	E	channel
1115	us trap	5/11/1989	900 AM			M	E	pool
1120	us trap	5/11/1989	900 AM	49		M	E	pool
1122	us trap	5/11/1989	900 AM	51		M	E	pool
1123	us trap	5/11/1989	900 AM	58		M	E	pool
1124	us trap	5/11/1989	920 AM	43		M	S	pool
1125	us trap	5/11/1989	920 AM	53		M	E	pool
1126	us trap	5/11/1989	920 AM	52		F	G	pool
1127	us trap	5/11/1989	940 AM	56		M	S	pool
1128	us trap	5/11/1989	940 AM	59		M	E	pool
7005	us trap	5/11/1989	940 AM	40	350	M	E	pool
1129,1130	us trap	5/11/1989	1000 AM	77	3200	F	E	pool
1017	us trap	5/11/1989	1000 AM	78		M	R	pool
1113	ds trap	5/11/1989	1030 AM	57	1125	F	S	channel
1111	ds trap	5/11/1989	1030 AM	53		M	S	channel
1131	ds trap	5/11/1989	1040 AM	43	1225			channel
1116	ds trap	5/11/1989	1040 AM	56	1350	M	E	channel
1112	ds trap	5/11/1989	1050 AM	46	600	M	E	channel
1052	ds trap	5/11/1989	1050 AM	59		F	R	channel
1132	ds trap	5/11/1989	1100 AM	55		M	E	channel
1133	us trap	5/12/1989	1000 AM	51	1025	M	S	retnr
1135	us trap	5/12/1989	1000 AM	59	1225		S	retnr
1136	us trap	5/12/1989	1000 AM	66	1900			retnr
1138	us trap	5/12/1989	1000 AM	54			S	retnr
1139	us trap	5/12/1989	1000 AM	64		M	E	retnr
1140	us trap	5/12/1989	1020 AM	67	1975	M	E	retnr
1141	us trap	5/12/1989	1020 AM	66		F	R	retnr
7023	us trap	5/12/1989	1020 AM	41		M	E	retnr
1143	us trap	5/12/1989	1020 AM	70		M	E	retnr
1144	us trap	5/12/1989	1020 AM	47			S	retnr
1145	us trap	5/12/1989	1040 AM	93		F	R	pool
1125	ds trap	5/12/1989	1100 AM	53		M	E	channel
1128	ds trap	5/12/1989	1100 AM	59		M	E	channel
1122	ds trap	5/12/1989	1100	51		M	E	channel
1114	ds trap	5/12/1989	1100 AM	47	750	M	S	channel
1108	ds trap	5/12/1989	1100 AM	49		F	S	channel
1017	ds trap	5/12/1989	1100 AM	78		M	R	channel
1147	ds trap	5/12/1989	1100 AM	52		M	E	channel
1135	retnr	5/12/1989	340 PM	59	1225		S	pool
1136	retnr	5/12/1989	340 PM	66	1900			pool
1140	retnr	5/12/1989	340 PM	67	1975	M	E	pool
1143	retnr	5/12/1989	340 PM	70		M	E	pool
1144	retnr	5/12/1989	340 PM	47			S	pool
1144	ds trap	5/13/1989	940 AM	47			S	channel
1129,1130	ds trap	5/13/1989	940 AM	77	3200	F	R	channel
1136	ds trap	5/13/1989	940 AM	66	1900	F	R	channel
1124	ds trap	5/13/1989	940 AM	43		M	S	channel
1123	ds trap	5/13/1989	940 AM	58		M	S	channel
1140	ds trap	5/13/1989	1000 AM	67	1975	M	E	channel
7005	ds trap	5/13/1989	1000 AM	40	350	M	S	channel

1143	ds trap	5/13/1989	1000 AM	70		M	S	channel
1135	ds trap	5/13/1989	1000 AM	59	1225		S	channel
1115	ds trap	5/13/1989	1000 AM	54	1150	M	S	channel
1145	ds trap	5/13/1989	1000 AM	93		F	R	channel
1109	ds trap	5/13/1989	1000 AM	55		M	E	channel
1133	retnr	5/13/1989	300 PM	51	1025	M	S	pool
1138	retnr	5/13/1989	300 PM	54			S	pool
1139	retnr	5/13/1989	300 PM	64		M	E	pool
1141	retnr	5/13/1989	300 PM	66		F	R	pool
7023	retnr	5/13/1989	300 PM	41		M	E	pool
1126	ds trap	5/13/1989	900 PM	52		F	E	channel
1141	ds trap	5/13/1989	900 PM	66		F	R	channel
1139	ds trap	5/13/1989	900 PM	64		M	E	channel
1150	us trap	5/14/1989	840 AM	57		F	R	pool
1150	ds trap	5/14/1990	720 PM	57		F	R	retnr
1150	retnr	5/15/1989	230 PM	57		F	R	pool
7023	us trap	5/15/1989	900 AM	48	1500		S	pool
1179	ds trap	5/15/1989	800 PM	49			S	retnr
7023	ds trap	5/15/1989	800 PM	41		M	S	channel
1150	ds trap	5/15/1989	800 PM	57		F	S	channel
1180	ds trap	5/16/1989	800 AM	54			S	retnr
1187	ds trap	5/17/1989	740 PM				S	channel
1180	ds trap	5/17/1989	740 PM				S	channel

Appendix 8. Tagging data for northern pike, Siisiip fishways, 1989.
(Records arranged by tag number)

( ) - signifies a tag originally applied but later removed or lost
[ ] - signifies a tag applied in the previous year
Two numbers separated by a comma signifies two tags applied to same fish
TAC signifies that the fish was tagged at the fishway exit
TDS signifies that the fish was tagged at the downstream trap

Tag Number	Capture Location	Date	Time	Fork Length (cm)	Weight (g)	Sex	Repro-ductive Condition	Release Location
1003	us trap	5/ 4/1989	940 AM	57		M	E	pool
1003	ds trap	5/ 5/1989	520 PM	57		M	E	channel
1004	us trap	5/ 4/1989	940 AM	55		M	G	pool
1004	ds trap	5/ 5/1989	520 PM	55		M	G	channel
1006	us trap	5/ 4/1989	940 AM	59		M	E	pool
1006	ds trap	5/ 5/1989	600 PM	59		M	E	channel
1007	us trap	5/ 4/1989	1000 AM	52		F	E	retnr
1007	ds trap	5/ 5/1989	520 PM	52		F	E	channel
1007	retnr	5/ 5/1989	700 AM	52		F	E	pool
1008	us trap	5/ 4/1989	940 AM	57		F	S	pool
1008	ds trap	5/ 5/1989	500 PM	57		F	S	channel
1009	us trap	5/ 4/1989	940 AM	56		M	E	pool
1011	us trap	5/ 4/1989	940 AM	67		F	R	pool
1011(1068)	ds trap	5/ 7/1989	320 PM	67	2100	F	R	channel
1012	us trap	5/ 4/1989	1000 AM	52		M	E	retnr
1012	retnr	5/ 5/1989	1130 AM	52		M	E	pool
1012	ds trap	5/ 5/1989	600 PM	52		M	E	channel
1014	us trap	5/ 4/1989	1000 AM	64		F	E	retnr
1014	ds trap	5/ 5/1989	600 PM	64		F	E	channel
1014	retnr	5/ 5/1989	700 AM	64		F	E	pool
1017	us trap	5/ 4/1989	1000 AM	78		M	E	retnr
1017	ds trap	5/ 5/1989	600 PM	78		M	E	channel
1017	retnr	5/ 5/1989	700 AM	78		M	E	pool
1017	us trap	5/11/1989	1000 AM	78		M	R	pool
1017	ds trap	5/12/1989	1100 AM	78		M	R	channel
1018	ds trap	5/ 5/1989	500 PM					channel
1019	us trap	5/ 4/1989	1000 AM	51		F	E	retnr
1019	ds trap	5/ 5/1989	540 PM	51		F	E	channel
1019	retnr	5/ 5/1989	700 AM	51		F	E	pool
1019	us trap	5/ 7/1989	1040 AM	51		F	R	pool
1019	ds trap	5/ 8/1989	940 PM	51		F	R	channel
1020	us trap	5/ 4/1989	1000 AM	61		F	E	retnr
1020	ds trap	5/ 5/1989	540 PM	61		F	E	channel
1020	retnr	5/ 5/1989	700 AM	61		F	E	pool
1022	us trap	5/ 4/1989	1000 AM	52		F	E	retnr
1022(1073)	ds trap	5/ 5/1989	620 PM	52		F	E	channel
1022(1073)	retnr	5/ 5/1989	700 AM	52		F	E	pool

1026	us trap	5/ 5/1989	1140 AM	55		S	pool
1026	ds trap	5/ 5/1989	520 PM	55		S	channel
1027	us trap	5/ 5/1989	1140 AM	51	M	S	pool
1027	ds trap	5/ 5/1989	520 PM	51	M	S	channel
1028	us trap	5/ 5/1989	1140 AM	61	F	G	pool
1028	ds trap	5/ 5/1989	600 PM	61	F	G	channel
1028	us trap	5/ 7/1989	1040 AM	61	F	G	pool
1028	ds trap	5/ 8/1989	1000 AM	61	F	E	channel
1029	us trap	5/ 5/1989	1140 AM	52	M	E	pool
1029	ds trap	5/ 7/1989	300 PM	52	M	S	channel
1031	us trap	5/ 5/1989	1140 AM	52	M	E	pool
1031	ds trap	5/ 5/1989	540 PM	52	M	E	channel
1032	us trap	5/ 5/1989	1140 AM	50	M	E	pool
1032	ds trap	5/ 7/1989	240 PM	50	M	E	channel
1032	ds trap	5/ 8/1989	940 AM	50	M	S	channel
1033	us trap	5/ 5/1989	1140 AM	51	M	E	pool
1033	ds trap	5/ 5/1989	600 PM	51	M	E	channel
1033	us trap	5/ 7/1989	1040 AM	51	M	E	pool
1033	ds trap	5/ 7/1989	200 PM	51	M	E	channel
1035	us trap	5/ 5/1989	1140 AM	47	M	E	pool
1035	ds trap	5/ 8/1989	1000 AM	47	M	S	channel
1036	us trap	5/ 5/1989	1200 PM	46	M	E	pool
1036	ds trap	5/ 5/1989	540 PM	46	M	E	channel
1037	us trap	5/ 5/1989	1200 PM	55	M	E	pool
1037	ds trap	5/ 5/1989	520 PM	55	M	E	channel
1038	us trap	5/ 5/1989	1200 PM	58	M	E	pool
1038	ds trap	5/ 8/1989	1015 AM	58	M	E	channel
1039	us trap	5/ 5/1989	1200 PM	61	M	E	pool
1040	us trap	5/ 5/1989	1200 PM	58	M	E	pool
1040	ds trap	5/ 5/1989	520 PM	58	M	E	channel
1040	us trap	5/ 7/1989	1120 AM	58	M	E	pool
1040	ds trap	5/ 8/1989	1000 AM	58	M	E	channel
1041	us trap	5/ 5/1989	1200 PM	51	F	E	pool
1041	ds trap	5/ 5/1989	540 PM	51	F	E	channel
1042	us trap	5/ 5/1989	1200 PM	52	M	E	pool
1042	ds trap	5/ 5/1989	540 PM	52	M	E	channel
1043	us trap	5/ 5/1989	1200 PM	53	M	E	pool
1044	us trap	5/ 5/1989	1220 PM	62	F	G	pool
1044	ds trap	5/ 7/1989	300 PM	62	F	E	channel
1045	us trap	5/ 5/1989	1220 PM	51	M	E	pool
1045	ds trap	5/ 5/1989	600 PM	51	M	E	channel
1046	us trap	5/ 5/1989	1220 PM	51	M	E	pool
1046	ds trap	5/ 5/1989	540 PM	51	M	R	channel
1047	us trap	5/ 5/1989	1220 PM	59	M	E	pool
1047	ds trap	5/ 5/1989	540 PM	59	M	E	channel
1048	us trap	5/ 5/1989	1220 PM	57	M	G	pool
1049	us trap	5/ 5/1989	1220 PM	62	M	E	pool
1049	ds trap	5/ 7/1989	300 PM	62	M	E	channel
1050	us trap	5/ 5/1989	1220 PM	56	F	G	pool
1050	ds trap	5/ 7/1989	200 PM	56	F	R	channel

1051	us trap	5/ 5/1989	1220 PM	51			G	pool
1051	ds trap	5/ 5/1989	600 PM	51			G	channel
1052	us trap	5/ 5/1989	1240 PM	59		F	R	pool
1052	ds trap	5/ 5/1989	500 PM	59		F	R	channel
1052	us trap	5/ 7/1989	1040 AM	59		F	R	pool
1052	ds trap	5/ 8/1989	1000 AM	59		F	R	channel
1052	retnr	5/ 9/1989	100 PM	59		F	R	pool
1052	us trap	5/ 9/1989	900 AM	59		F	R	retnr
1052	ds trap	5/11/1989	1050 AM	59		F	R	channel
1053	us trap	5/ 5/1989	1240 PM	62		M	E	pool
1053	ds trap	5/ 5/1989	500 PM	62		M	E	channel
1054	us trap	5/ 5/1989	1240 PM	48		M	E	pool
1054	ds trap	5/ 7/1989	300 PM	48		M	E	channel
1055	us trap	5/ 5/1989	1240 PM	52		M	E	pool
1055,1085	us trap	5/ 7/1989	1040 AM	52		M	S	pool
1055,1085	ds trap	5/ 8/1989	940 PM	52			S	channel
1056(1074)	us trap	5/ 5/1989	1240 PM	55		M	E	pool
1056(1074)	ds trap	5/ 5/1989	620 PM	55		M	E	channel
1057	us trap	5/ 5/1989	1240 PM	50		M	E	pool
1057	ds trap	5/ 5/1989	520 PM	50		M	E	channel
1058	us trap	5/ 5/1989	1240 PM	60			G	pool
1058	ds trap	5/ 5/1989	520 PM	60			G	channel
1058	ds trap	5/ 8/1989	940 PM	60			G	channel
1060	us trap	5/ 7/1989	1140 AM			F	R	pool
1060	ds trap	5/ 7/1989	300 PM			F	R	channel
1061	ds trap	5/ 5/1989	1000 PM	102		F	R	pool
1061	ds trap	5/ 5/1989	620 PM	102		F	R	channel
1061	us trap	5/ 7/1989	1120 AM	102		F	R	pool
1061	ds trap	5/ 7/1989	300 PM	102		F	R	channel
1062	ds trap	5/ 5/1989	1000 PM	82		F	R	pool
1062	ds trap	5/ 5/1989	600 PM	82		F	R	channel
1062	us trap	5/ 7/1989	1120 AM	82		F	R	pool
1062	ds trap	5/ 7/1989	300 PM	82		F	R	channel
1063,1066	ds trap	5/ 5/1989	1000 PM	91		F	R	pool
1063,1066	ds trap	5/ 8/1989	1000 AM	91		F		channel
1064	ds trap	5/ 5/1989	1000 PM	93		F	R	pool
1064	ds trap	5/ 5/1989	620 PM	93		F	R	channel
1071	ds trap	5/ 5/1989	640 PM	46		M	G	channel
1071	us trap	5/ 7/1989	1100 AM	46		M	G	pool
1071	ds trap	5/ 8/1989	940 PM	46		M	E	channel
1072	ds trap	5/ 5/1989	640 PM	55		M	E	channel
1075	ds trap	5/ 5/1989	640 PM	52		F	R	channel
1075	ds trap	5/ 7/1989	200 PM	52		F	R	channel
1076	ds trap	5/ 5/1989	640 PM	50		M	G	channel
1077	us trap	5/ 7/1989	1040 AM	52	950	M	E	pool
1077	ds trap	5/ 9/1989	930 AM	52	950	M	S	channel
1078	us trap	5/ 7/1989	1040 AM	47	775	M	E	pool
1078	ds trap	5/ 7/1989	200 PM	47	775	M	E	channel
1079	us trap	5/ 7/1989	1040 AM	53	825	F	R	pool
1079	ds trap	5/ 7/1989	240 PM	53	825	F	R	channel

1080	us trap	5/ 7/1989	1040 AM	57	1450	M	E	pool
1080	ds trap	5/ 8/1989	1000 AM	57	1450	M	E	channel
1081	us trap	5/ 7/1989	1040 AM	67	2200	M	E	pool
1083	us trap	5/ 7/1989	1040 AM	53	1000	M	S	pool
1083	ds trap	5/ 8/1989	1000 AM	53	1000	M	S	channel
1084	us trap	5/ 7/1989	1040 AM	52	950	F	R	pool
1084	ds trap	5/ 8/1989	940 PM	52	950	F	R	channel
1086	us trap	5/ 7/1989	1100 AM	66	1800	F	R	pool
1087	us trap	5/ 7/1989	1100 AM	64	1875	M	E	pool
1087	ds trap	5/ 8/1989	1000 AM	64	1875	M	E	channel
1088	us trap	5/ 7/1989	1100 AM	51	1000	M	E	pool
1089	us trap	5/ 7/1989	1100 AM	56	1350	M	E	pool
1089	ds trap	5/ 8/1989	940 AM	56	1350	M	E	channel
1090	us trap	5/ 7/1989	1100 AM	67	2400	F	E	pool
1090	ds trap	5/ 8/1989	940 PM	67	2400	F	R	channel
1091	us trap	5/ 7/1989	1120 AM	78	3500	M	E	pool
1091	ds trap	5/ 8/1989	940 PM	78	3500	M	E	channel
1092	ds trap	5/ 7/1989	200 PM	47	750	F	E	channel
1093	ds trap	5/ 7/1989	200 PM	51	850	M	E	channel
1094	ds trap	5/ 7/1989	220 PM	58	1275	M	E	channel
1095	ds trap	5/ 7/1989	220 PM	56	1350	M	E	channel
1096	ds trap	5/ 7/1989	220 PM	51	1000		G	channel
1097,1098	ds trap	5/ 7/1989	220 PM	94		F	R	channel
1099	ds trap	5/ 7/1989	220 PM	55	1175	M	R	channel
1100	ds trap	5/ 7/1989	240 PM	51	1000	M	E	channel
1101	ds trap	5/ 7/1989	240 PM	55	1100	M	E	channel
1102	ds trap	5/ 7/1989	240 PM	49	750	M	E	channel
1103	ds trap	5/ 7/1989	300 PM	51	975	M	E	channel
1104	ds trap	5/ 7/1989	300 PM	53	1025	F	R	channel
1106	ds trap	5/ 8/1989	940 PM	73	3200	F	E	channel
1107	ds trap	5/ 8/1989	1000 AM	46	650	M	E	channel
1108	retnr	5/ 9/1989	100 PM	49		F	S	pool
1108	us trap	5/ 9/1989	900 AM	49		F	S	retnr
1108	ds trap	5/12/1989	1100 AM	49		F	S	channel
1109	retnr	5/ 9/1989	100 PM	55		M	E	pool
1109	us trap	5/ 9/1989	900 AM	55		M	E	retnr
1109	ds trap	5/13/1989	1000 AM	55		M	E	channel
1111	retnr	5/ 9/1989	100 PM	53		M	E	pool
1111	us trap	5/ 9/1989	900 AM	53		M	E	retnr
1111	ds trap	5/11/1989	1030 AM	53		M	S	channel
1112	us trap	5/10/1989	1000 AM	46	600	M	E	retnr
1112	retnr	5/10/1989	500 PM	46	600	M	E	pool
1112	ds trap	5/11/1989	1050 AM	46	600	M	E	channel
1113	us trap	5/10/1989	1000 AM	57	1125	F	S	retnr
1113	retnr	5/10/1989	500 PM	57	1125	F	S	pool
1113	ds trap	5/11/1989	1030 AM	57	1125	F	S	channel
1114	us trap	5/10/1989	1000 AM	47	750	M	E	retnr
1114	retnr	5/10/1989	500 PM	47	750	M	E	pool
1114	ds trap	5/12/1989	1100 AM	47	750	M	S	channel
1115	us trap	5/10/1989	1000 PM	54	1150	M	E	retnr

1115	retnr	5/10/1989	500 PM	54	1150	M	E	pool
1115	us trap	5/11/1989	900 AM			M	E	pool
1115	ds trap	5/13/1989	1000 AM	54	1150	M	S	channel
1116	us trap	5/10/1989	1000 AM	56	1350	M	E	retnr
1116	retnr	5/10/1989	500 PM	56	1350	M	E	pool
1116	ds trap	5/11/1989	1040 AM	56	1350	M	E	channel
1117	us trap	5/10/1989	1000 AM	62	1675	F	G	retnr
1117	retnr	5/10/1989	500 PM	62	1675	F	G	pool
1120	us trap	5/11/1989	900 AM	49		M	E	pool
1122	us trap	5/11/1989	900 AM	51		M	E	pool
1122	ds trap	5/12/1989	1100	51		M	E	channel
1123	us trap	5/11/1989	900 AM	58		M	E	pool
1123	ds trap	5/13/1989	940 AM	58		M	S	channel
1124	us trap	5/11/1989	920 AM	43		M	S	pool
1124	ds trap	5/13/1989	940 AM	43		M	S	channel
1125	us trap	5/11/1989	920 AM	53		M	E	pool
1125	ds trap	5/12/1989	1100 AM	53		M	E	channel
1126	us trap	5/11/1989	920 AM	52		F	G	pool
1126	ds trap	5/13/1989	900 PM	52		F	E	channel
1127	us trap	5/11/1989	940 AM	56		M	S	pool
1128	us trap	5/11/1989	940 AM	59		M	E	pool
1128	ds trap	5/12/1989	1100 AM	59		M	E	channel
1129,1130	us trap	5/11/1989	1000 AM	77	3200	F	E	pool
1129,1130	ds trap	5/13/1989	940 AM	77	3200	F	R	channel
1131	ds trap	5/11/1989	1040 AM	43	1225			channel
1132	ds trap	5/11/1989	1100 AM	55		M	E	channel
1133	us trap	5/12/1989	1000 AM	51	1025	M	S	retnr
1133	retnr	5/13/1989	300 PM	51	1025	M	S	pool
1135	us trap	5/12/1989	1000 AM	59	1225		S	retnr
1135	retnr	5/12/1989	340 PM	59	1225		S	pool
1135	ds trap	5/13/1989	1000 AM	59	1225		S	channel
1136	us trap	5/12/1989	1000 AM	66	1900			retnr
1136	retnr	5/12/1989	340 PM	66	1900			pool
1136	ds trap	5/13/1989	940 AM	66	1900	F	R	channel
1138	us trap	5/12/1989	1000 AM	54			S	retnr
1138	retnr	5/13/1989	300 PM	54			S	pool
1139	us trap	5/12/1989	1000 AM	64		M	E	retnr
1139	retnr	5/13/1989	300 PM	64		M	E	pool
1139	ds trap	5/13/1989	900 PM	64		M	E	channel
1140	us trap	5/12/1989	1020 AM	67	1975	M	E	retnr
1140	retnr	5/12/1989	340 PM	67	1975	M	E	pool
1140	ds trap	5/13/1989	1000 AM	67	1975	M	E	channel
1141	us trap	5/12/1989	1020 AM	66		F	R	retnr
1141	retnr	5/13/1989	300 PM	66		F	R	pool
1141	ds trap	5/13/1989	900 PM	66		F	R	channel
1143	us trap	5/12/1989	1020 AM	70		M	E	retnr
1143	retnr	5/12/1989	340 PM	70		M	E	pool
1143	ds trap	5/13/1989	1000 AM	70		M	S	channel
1144	us trap	5/12/1989	1020 AM	47			S	retnr
1144	retnr	5/12/1989	340 PM	47			S	pool

1144	ds trap	5/13/1989	940 AM	47			S	channel
1145	us trap	5/12/1989	1040 AM	93		F	R	pool
1145	ds trap	5/13/1989	1000 AM	93		F	R	channel
1147	ds trap	5/12/1989	1100 AM	52		M	E	channel
1150	us trap	5/14/1989	840 AM	57		F	R	pool
1150	retnr	5/15/1989	230 PM	57		F	R	pool
1150	ds trap	5/15/1989	800 PM	57		F	S	channel
1150	ds trap	5/14/1990	720 PM	57		F	R	retnr
1179	ds trap	5/15/1989	800 PM	49			S	retnr
1180	ds trap	5/16/1989	800 AM	54			S	retnr
1180	ds trap	5/17/1989	740 PM				S	channel
1187	ds trap	5/17/1989	740 PM				S	channel
7002	us trap	5/ 4/1989	1000 AM	42		M	E	retnr
7002	ds trap	5/ 5/1989	540 PM	42		M	E	channel
7002	retnr	5/ 5/1989	700 AM	42		M	E	pool
7004	ds trap	5/10/1989	1030 AM			M	E	channel
7005	us trap	5/11/1989	940 AM	40	350	M	E	pool
7005	ds trap	5/13/1989	1000 AM	40	350	M	S	channel
7023	us trap	5/12/1989	1020 AM	41		M	E	retnr
7023	retnr	5/13/1989	300 PM	41		M	E	pool
7023	ds trap	5/15/1989	800 PM	41		M	S	channel
7023	us trap	5/15/1989	900 AM	48	1500		S	pool
7024	ds trap	5/ 7/1989	300 PM	42	475	M	E	channel

Appendix 9. Tagging data for northern pike, Siisiip fishways, 1990.
(Records arranged chronologically)

( ) - signifies a tag originally applied but later removed or lost
[ ] - signifies a tag applied in the previous year
Two numbers separated by a comma signifies two tags applied to same fish
TAC signifies that the fish was tagged at the fishway exit
TDS signifies that the fish was tagged at the downstream trap

Tag Number	Capture Location	Date	Time	Fork Length (cm)	Weight (g)	Sex	Reproductive Condition	Release Location
1153	steep	5/ 4/1990	700 AM	57			G	marsh
1156	stand	5/ 5/1990	700 AM	62		F	E	marsh
1158	stand	5/ 5/1990	700 AM	47			G	marsh
1155	stand	5/ 5/1990	700 AM	40		M	E	marsh
1154	steep	5/ 5/1990	700 AM	57		F	E	marsh
1162	steep	5/ 5/1990	700 AM	42			G	marsh
1160	steep	5/ 5/1990	700 AM	61		M	E	marsh
1166	gill net	5/ 5/1990	700 PM	46		M	E	pool
7007	gill net	5/ 5/1990	700 PM	37		M	E	pool
1165	stand	5/ 5/1990	700 PM	57	1175	M	E	marsh
1167	stand	5/ 5/1990	700 PM	46	850		G	marsh
1164	stand	5/ 5/1990	700 PM	43	700		G	marsh
1163	steep	5/ 5/1990	700 PM	46		F	R	marsh
1169	steep	5/ 5/1990	700 PM	56	1250	M	E	marsh
1171	steep	5/ 5/1990	700 PM	52	1100	F	E	marsh
7008	stand	5/ 6/1990	700 AM	42		M	E	marsh
1193	stand	5/ 6/1990	700 AM	50			G	marsh
1197	stand	5/ 6/1990	700 AM	57		M	R	marsh
1192	steep	5/ 6/1990	700 AM	59			G	marsh
1189	steep	5/ 6/1990	700 AM	53		M	R	marsh
1172	steep	5/ 6/1990	700 AM	63	2300		G	marsh
1188	steep	5/ 6/1990	700 AM	43			G	marsh
1174	steep	5/ 6/1990	700 AM	53	1100	M	S?	marsh
1401	gill net	5/ 6/1990	700 PM	42		F	S?	pool
1404	gill net	5/ 6/1990	700 PM	57		M	R	pool
1405	gill net	5/ 6/1990	700 PM	57		M	R	pool
1199	gill net	5/ 6/1990	700 PM	56		M	E	pool
1407	gill net	5/ 6/1990	700 PM	47			G	pool
1408	gill net	5/ 6/1990	700 PM	41		M	S?	pool
1198	gill net	5/ 6/1990	700 PM	45			G	pool
1200	gill net	5/ 6/1990	700 PM	52		M	E	pool
1406	stand	5/ 6/1990	700 PM	57		M	E	marsh
1196	standard	5/ 6/1990	700 PM	58			G	marsh
1411	stand	5/ 7/1990	700 AM	51		M	R	marsh
1409	stand	5/ 7/1990	700 AM	60			G	marsh
7022	stand	5/ 7/1990	700 AM	37		F	R	marsh
1410	stand	5/ 7/1990	700 AM	46			G	marsh
7010	gill net	5/ 7/1990	700 PM	44		M	E	pool

7010	gill net	5/ 7/1990	700 PM					pool
7011	gill net	5/ 7/1990	700 PM	29			G or I	pool
7028	gill net	5/ 7/1990	700 PM	67		M	S	pool
7010(7031)	gill net	5/ 7/1990	700 PM	44		M	E	pool
7030	gill net	5/ 7/1990	700 PM	39		M	R	pool
7027	gill net	5/ 7/1990	700 PM	46		M	E	pool
7015	gill net	5/ 7/1990	700 PM	52		M	E	pool
7026	stand	5/ 7/1990	700 PM	72	3100	M	E	marsh
7012	steep	5/ 7/1990	700 PM	40			G	marsh
7032	steep	5/ 7/1990	700 PM	39		F	R	marsh
1166	steep	5/ 7/1990	700 PM			M	E orS	marsh
7045	steep	5/ 7/1990	700 PM	43			S?	marsh
7013	steep	5/ 7/1990	700 PM	57		M	E	marsh
7029	steep	5/ 7/1990	700 PM	65			G	marsh
7034	gill net	5/ 8/1990	700 AM	51			G	pool
7043	gill net	5/ 8/1990	700 PM	53		M	E	pool
7053	gill net	5/ 8/1990	700 PM	58		M	E	pool
7036	gill net	5/ 8/1990	700 PM	55	1175	M	R	pool
7040	gill net	5/ 8/1990	700 PM	27			I	pool
7038	gill net	5/ 8/1990	700 PM	53		M	R	pool
7039	gill net	5/ 8/1990	700 PM	57	1500	M	R	pool
7051	gill net	5/ 8/1990	700 PM	53			S	pool
7035	gill net	5/ 8/1990	700 PM	27	130	M	E	pool
7037	gill net	5/ 8/1990	700 PM	53	1225	M	R	pool
7049	gill net	5/ 8/1990	700 PM	57		M	R	pool
7046	stand	5/ 8/1990	700 PM	63		M	E	marsh
7048	stand	5/ 8/1990	700 PM	41		M	S	marsh
7044	stand	5/ 8/1990	700 PM	44		F	R	marsh
7055	gill net	5/ 9/1990	700 AM	53		M	R	pool
7054	gill net	5/ 9/1990	700 AM	53		M	E	pool
7056	stand	5/ 9/1990	700 AM	45		M	E	marsh
7059	steep	5/ 9/1990	700 AM	42		F	R	marsh
7058	steep	5/ 9/1990	700 AM	54		M	S	marsh
7061	steep	5/ 9/1990	700 AM	60			G	marsh
7057	steep	5/ 9/1990	700 AM	52		M	S?	marsh
7062	gill net	5/ 9/1990	700 PM	52		F	R	pool
7064	gill net	5/ 9/1990	700 PM	44		F	R	pool
7036	gill net	5/ 9/1990	700 PM					pool
7063	gill net	5/ 9/1990	700 PM	47			S	pool
1412	stand	5/ 9/1990	700 PM	89	5800	F	E	marsh
7065	gill net	5/10/1990	700 AM	64		M	E	pool
7067	stand	5/10/1990	700 AM	54		M	E	marsh
7068	steep	5/10/1990	700 AM	39		F	E	marsh
7066	gill net	5/10/1990	700 AM	54		M	R	pool
7072	stand	5/10/1990	700 PM	57		F	R	marsh
7071	steep	5/10/1990	700 PM	44		F	R	marsh
7070	steep	5/10/1990	700 PM	41		M	E	marsh
7073	stand	5/11/1990	700 AM	47			S	marsh
7074	steep	5/11/1990	700 AM	51			S	marsh
7078	gill net	5/11/1990	700 PM	42	425		S	pool

7066	gill net	5/11/1990	700 PM					pool
7079	gill net	5/11/1990	700 PM	59		M	E	pool
7081	steep	5/11/1990	700 PM	48		M	E	marsh
7077[1044]	steep	5/11/1990	700 PM	64	2400		S?	marsh
7085	gill net	5/12/1990	700 AM	67			S	pool
7086	gill net	5/12/1990	700 AM	54			S	pool
7087	gill net	5/12/1990	700 AM	58		M	E or S	pool
7082	gill net	5/12/1990	700 AM	56		F	S	pool
7084	gill net	5/12/1990	700 AM	56		M	E	pool
7089	stand	5/12/1990	700 AM	64		F	E orS	marsh
7088	stand	5/12/1990	700 AM	49		F	E	marsh
7053	steep	5/12/1990	700 AM			M	S?	marsh
7091	gill net	5/12/1990	700 PM	70	2500		S	pool
7090	stand	5/12/1990	700 PM	51		M	S?	marsh
7092	gill net	5/13/1990	700 AM	55		M	E	pool
7093	stand	5/13/1990	700 AM	57				marsh
7202TAC	steep	5/13/1990	700 PM	58		M	E or S	marsh
7095,7201	ds trap	5/13/1990	700 PM					acc chan
7095,7096	us trap	5/13/1990	700 PM	45	650		S	pool
7098	us trap	5/13/1990	700 PM	49	850	M	S?	pool
7099	us trap	5/13/1990	700 PM	57	1425	M	R	pool
1414	us trap	5/13/1990	700 PM	77	3900	M	R	pool
1414	ds trap	5/14/1990	700 AM			M	E	acc chan
7099	stand	5/14/1990	700 AM					marsh
7205	us trap	5/14/1990	700 AM	44	725	M	S	pool
7204	us trap	5/14/1990	700 AM	46	700	M	E	pool
7208	us trap	5/14/1990	700 AM	44	575	M	S	pool
7209	us trap	5/14/1990	700 AM	52	1050	F	R	pool
7210	us trap	5/14/1990	700 AM	40	400	M	E	pool
7095,7201	us trap	5/14/1990	700 AM				S?	pool
7203	us trap	5/14/1990	700 AM	43	500		S	pool
7206	us trap	5/14/1990	700 AM	62				pool
7210	stand	5/14/1990	700 PM					marsh
7208	steep	5/14/1990	700 PM					marsh
7095,7201	steep	5/14/1990	700 PM					retnr
7205	steep	5/14/1990	700 PM					retnr
7206	steep	5/14/1990	700 PM					marsh
7203	steep	5/14/1990	700 PM				S	marsh
7230	ds trap	5/15/1990	700 AM	41	550	M	S	acc chan
7054	ds trap	5/15/1990	700 AM			M	E	acc chan
7220	lead ds>	5/15/1990	700 AM				S	acc chan
7217	us trap	5/15/1990	700 AM	51		M	E	pool
7218	us trap	5/15/1990	700 AM	55		M	E	pool
7219	us trap	5/15/1990	700 AM	50		F	S	pool
7220	us trap	5/15/1990	700 AM	65	1775		S	pool
1418	us trap	5/15/1990	700 AM	70	3000		S?	pool
7221	us trap	5/15/1990	700 AM	43	625	F	R	pool
7222	us trap	5/15/1990	700 AM	53	1300	F	R	pool
7223	us trap	5/15/1990	700 AM	54		M	E	pool
7224	us trap	5/15/1990	700 AM	66		M	R	pool

7225	us trap	5/15/1990	700 AM	46			S	pool
7216	us trap	5/15/1990	700 AM	58	1400	M	E	pool
7227	us trap	5/15/1990	700 AM	52	950	M	E	pool
7228	us trap	5/15/1990	700 AM	57	1350	M	E	pool
7229	us trap	5/15/1990	700 AM	64		F	R	pool
7215	us trap	5/15/1990	700 AM	57	1025	M	E	pool
7214	us trap	5/15/1990	700 AM	41	500		S	pool
7213	us trap	5/15/1990	700 AM	41	475	M	E	pool
7226	us trap	5/15/1990	700 AM	60	2100		S	pool
7054	us trap	5/15/1990	700 AM			M	E	pool
7212	us trap	5/15/1990	700 AM	47	800	F	S	pool
7219	lead ds>	5/15/1990	700 PM					acc chan
7215	lead ds>	5/15/1990	700 PM					acc chan
7229	stand	5/15/1990	700 PM					retnr
7216	stand	5/15/1990	700 PM					retnr
7214	stand	5/15/1990	700 PM					retnr
7217	stand	5/15/1990	700 PM					retnr
7222	steep	5/15/1990	700 PM					retnr
7231TAC	steep	5/15/1990	700 PM	41	500	M	S	retnr
7221	steep	5/15/1990	700 PM					retnr
7227	ds trap	5/16/1990	700 AM				S	acc chan
7223	ds trap	5/16/1990	700 AM				S	acc chan
7232TAC	stand	5/16/1990	700 AM	43	525	M	E	retnr
7234TAC	stand	5/16/1990	700 AM	49	850	M	R	retnr
7224	steep	5/16/1990	700 AM			M	R	retnr
7233TAC	steep	5/16/1990	700 AM	52	1100	M	E	retnr
7239	us trap	5/16/1990	700 AM	58	1325	M	R	pool
7236	us trap	5/16/1990	700 AM	53	1100	M	R	retnr
7237	us trap	5/16/1990	700 AM	54	1300	M	R	pool
7238	us trap	5/16/1990	700 AM	44	650	M	S	pool
7237	ds trap	5/16/1990	700 PM			M	R	acc chan
1418	ds trap	5/16/1990	700 PM				S	acc chan
7228	ds trap	5/16/1990	700 PM				S	acc chan
7218	ds trap	5/16/1990	700 PM				S	acc chan
7238	ds trap	5/16/1990	700 PM				S	acc chan
7241	lead us>	5/16/1990	700 PM	31	220	M	S	pool
7236	retnr	5/16/1990	700 PM					pool
7239	stand	5/16/1990	700 PM					timtri
7240TAC	steep	5/16/1990	700 PM	37	425	F	E	retnr
7235	us trap	5/16/1990	700 AM	46	625	M	S	pool
7317TDS	ds trap	5/17/1990	700 AM	60	1450			acc chan
7236	ds trap	5/17/1990	700 AM				S	acc chan
7226	ds trap	5/17/1990	700 AM				S	acc chan
7235	ds trap	5/17/1990	700 AM				S	acc chan
7316TDS	ds trap	5/17/1990	700 AM	25	90		I	acc chan
7242TAC	steep	5/17/1990	700 AM	42	625	M	R	retnr
7255	us trap	5/17/1990	700 AM	59	1350	M	E	pool
7248	us trap	5/17/1990	700 AM	62	1675	M	E	pool
1420	us trap	5/17/1990	700 AM	64	2100		S	pool
7252[1045]	us trap	5/17/1990	700 AM	55	1325	M	R	pool

7245	us trap	5/17/1990	700 AM	51	950		S	pool
7251	us trap	5/17/1990	700 AM	66	2100	M	R	pool
7258	us trap	5/17/1990	700 AM	53	1125	M	R	pool
7306	us trap	5/17/1990	700 AM	61	1950	M	S	pool
7244	us trap	5/17/1990	700 AM	57	1300	M	E	pool
7247	us trap	5/17/1990	700 AM	43	625	M	E	pool
7243	us trap	5/17/1990	700 AM	43	575		S	pool
7237	us trap	5/17/1990	700 AM			M	R	pool
7253	us trap	5/17/1990	700 AM	59	1800		S	pool
7318TAC	stand	5/17/1990	700 PM	40	475		S	retnr
7320TAC	steep	5/17/1990	700 PM	34	300	M	E or S	retnr
7252	steep	5/17/1990	700 PM				E or S	retnr
7319TAC	steep	5/17/1990	700 PM	37	400	M	E	retnr
7247	steep	5/17/1990	700 PM				S	retnr
7245	steep	5/17/1990	700 PM				S	retnr
7251	ds trap	5/18/1990	700 AM					acc chan
7255	ds trap	5/18/1990	700 AM				S	acc chan
7258	ds trap	5/18/1990	700 AM				S	acc chan
7363TDS	ds trap	5/18/1990	700 AM	46	775		S	acc chan
1420	ds trap	5/18/1990	700 AM				S	acc chan
7253	ds trap	5/18/1990	700 AM				S	acc chan
7326TAC	steep	5/18/1990	700 AM	49	750		S	retnr
7335	us trap	5/18/1990	700 AM	47	750		S	pool
7352	us trap	5/18/1990	700 AM	44	900	M	S	pool
7333	us trap	5/18/1990	700 AM	55	1200	M	R	pool
7354	us trap	5/18/1990	700 AM	44	650	F	S	pool
7332	us trap	5/18/1990	700 AM	45	900		S	pool
7327	us trap	5/18/1990	700 AM	65	1750	M	R	pool
7337	us trap	5/18/1990	700 AM	59	1800	M	E or S	pool
7338	us trap	5/18/1990	700 AM	55	1100		S	pool
7334	us trap	5/18/1990	700 AM	51	1000		S	pool
7327	ds trap	5/18/1990	700 PM			M	R	acc chan
7364TAC	stand	5/18/1990	700 PM	52	1025	M	R	retnr
7334	steep	5/18/1990	700 PM				S	retnr
7367TDS	ds trap	5/19/1990	700 AM	66	2000	F	S	acc chan
7248	ds trap	5/19/1990	700 AM			M	R	acc chan
7365	us trap	5/19/1990	700 AM	58	1700	M	E	pool
7367	ds trap	5/20/1990	700 AM					acc chan
7372[1080]	ds trap	5/20/1990	700 AM	61	2200	M	E	acc chan
7371TDS	ds trap	5/20/1990	700 AM	51	1650	M	S	acc chan
7365	ds trap	5/20/1990	700 AM				E	acc chan
7333	ds trap	5/20/1990	700 AM			M	E	acc chan
7337	ds trap	5/20/1990	700 AM				S	acc chan
7335	ds trap	5/20/1990	700 AM				S	acc chan
7352	ds trap	5/20/1990	700 AM				S	acc chan
7224	ds trap	5/20/1990	700 AM				R	acc chan
7354	ds trap	5/20/1990	700 AM				S	acc chan
7326	pool	5/20/1990	700 AM					acc chan
7332	pool	5/20/1990	700 AM					acc chan
7377TDS	ds trap	5/20/1990	700 PM	59	1400	M	R	acc chan

7338	ds trap	5/20/1990	700 PM				S	acc chan
no tag	pool	5/20/1990	700 PM	63	2200	F	S	dead
7393TDS	ds trap	5/21/1990	700 AM	58	1700	M	R	acc chan
7384TDS	ds trap	5/21/1990	700 AM	39	450	M	R	retnr
7394TDS	ds trap	5/21/1990	700 AM	47	800	M	R	acc chan
7383TDS	ds trap	5/21/1990	700 AM	51	900	M	R	retnr
7241	lead	5/21/1990	700 PM					dead
7011	lead	5/21/1990	700 PM					dead

Appendix 10. Tagging data for northern pike, Siisiip fishways, 1990.
(Records arranged by tag number)

(   ) - signifies a tag originally applied but later removed or lost
[   ] - signifies a tag applied in the previous year
Two numbers separated by a comma signifies two tags applied to same fish
TAC signifies that the fish was tagged at the fishway exit
TDS signifies that the fish was tagged at the downstream trap

Tag Number	Capture Location	Date	Time	Fork Length (cm)	Weight (g)	Sex	Reproductive Condition	Release Location
1153	steep	5/ 4/1990	700 AM	57			G	marsh
1154	steep	5/ 5/1990	700 AM	57		F	E	marsh
1155	stand	5/ 5/1990	700 AM	40		M	E	marsh
1156	stand	5/ 5/1990	700 AM	62		F	E	marsh
1158	stand	5/ 5/1990	700 AM	47			G	marsh
1160	steep	5/ 5/1990	700 AM	61		M	E	marsh
1162	steep	5/ 5/1990	700 AM	42			G	marsh
1163	steep	5/ 5/1990	700 PM	46		F	R	marsh
1164	stand	5/ 5/1990	700 PM	43	700		G	marsh
1165	stand	5/ 5/1990	700 PM	57	1175	M	E	marsh
1166	gill net	5/ 5/1990	700 PM	46		M	E	pool
1166	steep	5/ 7/1990	700 PM			M	E orS	marsh
1167	stand	5/ 5/1990	700 PM	46	850		G	marsh
1169	steep	5/ 5/1990	700 PM	56	1250	M	E	marsh
1171	steep	5/ 5/1990	700 PM	52	1100	F	E	marsh
1172	steep	5/ 6/1990	700 AM	63	2300		G	marsh
1174	steep	5/ 6/1990	700 AM	53	1100	M	S?	marsh
1188	steep	5/ 6/1990	700 AM	43			G	marsh
1189	steep	5/ 6/1990	700 AM	53		M	R	marsh
1192	steep	5/ 6/1990	700 AM	59			G	marsh
1193	stand	5/ 6/1990	700 AM	50			G	marsh
1196	standard	5/ 6/1990	700 PM	58			G	marsh
1197	stand	5/ 6/1990	700 AM	57		M	R	marsh
1198	gill net	5/ 6/1990	700 PM	45			G	pool
1199	gill net	5/ 6/1990	700 PM	56		M	E	pool
1200	gill net	5/ 6/1990	700 PM	52		M	E	pool
1401	gill net	5/ 6/1990	700 PM	42		F	S?	pool
1404	gill net	5/ 6/1990	700 PM	57		M	R	pool
1405	gill net	5/ 6/1990	700 PM	57		M	R	pool
1406	stand	5/ 6/1990	700 PM	57		M	E	marsh
1407	gill net	5/ 6/1990	700 PM	47			G	pool
1408	gill net	5/ 6/1990	700 PM	41		M	S?	pool
1409	stand	5/ 7/1990	700 AM	60			G	marsh
1410	stand	5/ 7/1990	700 AM	46			G	marsh
1411	stand	5/ 7/1990	700 AM	51		M	R	marsh
1412	stand	5/ 9/1990	700 PM	89	5800	F	E	marsh
1414	us trap	5/13/1990	700 PM	77	3900	M	R	pool
1414	ds trap	5/14/1990	700 AM			M	E	acc chan

1418	us trap	5/15/1990	700 AM	70	3000		S?	pool
1418	ds trap	5/16/1990	700 PM				S	acc chan
1420	us trap	5/17/1990	700 AM	64	2100		S	pool
1420	ds trap	5/18/1990	700 AM				S	acc chan
7007	gill net	5/ 5/1990	700 PM	37		M	E	pool
7008	stand	5/ 6/1990	700 AM	42		M	E	marsh
7010	gill net	5/ 7/1990	700 PM	44		M	E	pool
7010	gill net	5/ 7/1990	700 PM					pool
7010(7031)	gill net	5/ 7/1990	700 PM	44		M	E	pool
7011	gill net	5/ 7/1990	700 PM	29			G or I	pool
7011	lead	5/21/1990	700 PM					dead
7012	steep	5/ 7/1990	700 PM	40			G	marsh
7013	steep	5/ 7/1990	700 PM	57		M	E	marsh
7015	gill net	5/ 7/1990	700 PM	52		M	E	pool
7022	stand	5/ 7/1990	700 AM	37		F	R	marsh
7026	stand	5/ 7/1990	700 PM	72	3100	M	E	marsh
7027	gill net	5/ 7/1990	700 PM	46		M	E	pool
7028	gill net	5/ 7/1990	700 PM	67		M	S	pool
7029	steep	5/ 7/1990	700 PM	65			G	marsh
7030	gill net	5/ 7/1990	700 PM	39		M	R	pool
7032	steep	5/ 7/1990	700 PM	39		F	R	marsh
7034	gill net	5/ 8/1990	700 AM	51			G	pool
7035	gill net	5/ 8/1990	700 PM	27	130	M	E	pool
7036	gill net	5/ 8/1990	700 PM	55	1175	M	R	pool
7036	gill net	5/ 9/1990	700 PM					pool
7037	gill net	5/ 8/1990	700 PM	53	1225	M	R	pool
7038	gill net	5/ 8/1990	700 PM	53		M	R	pool
7039	gill net	5/ 8/1990	700 PM	57	1500	M	R	pool
7040	gill net	5/ 8/1990	700 PM	27			I	pool
7043	gill net	5/ 8/1990	700 PM	53		M	E	pool
7044	stand	5/ 8/1990	700 PM	44		F	R	marsh
7045	steep	5/ 7/1990	700 PM	43			S?	marsh
7046	stand	5/ 8/1990	700 PM	63		M	E	marsh
7048	stand	5/ 8/1990	700 PM	41		M	S	marsh
7049	gill net	5/ 8/1990	700 PM	57		M	R	pool
7051	gill net	5/ 8/1990	700 PM	53			S	pool
7053	gill net	5/ 8/1990	700 PM	58		M	E	pool
7053	steep	5/12/1990	700 AM			M	S?	marsh
7054	gill net	5/ 9/1990	700 AM	53		M	E	pool
7054	ds trap	5/15/1990	700 AM			M	E	acc chan
7054	us trap	5/15/1990	700 AM			M	E	pool
7055	gill net	5/ 9/1990	700 AM	53		M	R	pool
7056	stand	5/ 9/1990	700 AM	45		M	E	marsh
7057	steep	5/ 9/1990	700 AM	52		M	S?	marsh
7058	steep	5/ 9/1990	700 AM	54		M	S	marsh
7059	steep	5/ 9/1990	700 AM	42		F	R	marsh
7061	steep	5/ 9/1990	700 AM	60			G	marsh
7062	gill net	5/ 9/1990	700 PM	52		F	R	pool
7063	gill net	5/ 9/1990	700 PM	47			S	pool
7064	gill net	5/ 9/1990	700 PM	44		F	R	pool

7065	gill net	5/10/1990	700 AM	64		M	E	pool
7066	gill net	5/10/1990	700 AM	54		M	R	pool
7066	gill net	5/11/1990	700 PM					pool
7067	stand	5/10/1990	700 AM	54		M	E	marsh
7068	steep	5/10/1990	700 AM	39		F	E	marsh
7070	steep	5/10/1990	700 PM	41		M	E	marsh
7071	steep	5/10/1990	700 PM	44		F	R	marsh
7072	stand	5/10/1990	700 PM	57		F	R	marsh
7073	stand	5/11/1990	700 AM	47			S	marsh
7074	steep	5/11/1990	700 AM	51			S	marsh
7077[1044]	steep	5/11/1990	700 PM	64	2400		S?	marsh
7078	gill net	5/11/1990	700 PM	42	425		S	pool
7079	gill net	5/11/1990	700 PM	59		M	E	pool
7081	steep	5/11/1990	700 PM	48		M	E	marsh
7082	gill net	5/12/1990	700 AM	56		F	S	pool
7084	gill net	5/12/1990	700 AM	56		M	E	pool
7085	gill net	5/12/1990	700 AM	67			S	pool
7086	gill net	5/12/1990	700 AM	54			S	pool
7087	gill net	5/12/1990	700 AM	58		M	E or S	pool
7088	stand	5/12/1990	700 AM	49		F	E	marsh
7089	stand	5/12/1990	700 AM	64		F	E orS	marsh
7090	stand	5/12/1990	700 PM	51		M	S?	marsh
7091	gill net	5/12/1990	700 PM	70	2500		S	pool
7092	gill net	5/13/1990	700 AM	55		M	E	pool
7093	stand	5/13/1990	700 AM	57				marsh
7095,7096	us trap	5/13/1990	700 PM	45	650		S	pool
7095,7201	ds trap	5/13/1990	700 PM					acc chan
7095,7201	us trap	5/14/1990	700 AM				S?	pool
7095,7201	steep	5/14/1990	700 PM					retnr
7098	us trap	5/13/1990	700 PM	49	850	M	S?	pool
7099	us trap	5/13/1990	700 PM	57	1425	M	R	pool
7099	stand	5/14/1990	700 AM					marsh
7202TAC	steep	5/13/1990	700 PM	58		M	E or S	marsh
7203	us trap	5/14/1990	700 AM	43	500		S	pool
7203	steep	5/14/1990	700 PM				S	marsh
7204	us trap	5/14/1990	700 AM	46	700	M	E	pool
7205	us trap	5/14/1990	700 AM	44	725	M	S	pool
7205	steep	5/14/1990	700 PM					retnr
7206	us trap	5/14/1990	700 AM	62				pool
7206	steep	5/14/1990	700 PM					marsh
7208	us trap	5/14/1990	700 AM	44	575	M	S	pool
7208	steep	5/14/1990	700 PM					marsh
7209	us trap	5/14/1990	700 AM	52	1050	F	R	pool
7210	us trap	5/14/1990	700 AM	40	400	M	E	pool
7210	stand	5/14/1990	700 PM					marsh
7212	us trap	5/15/1990	700 AM	47	800	F	S	pool
7213	us trap	5/15/1990	700 AM	41	475	M	E	pool
7214	us trap	5/15/1990	700 AM	41	500		S	pool
7214	stand	5/15/1990	700 PM					retnr
7215	us trap	5/15/1990	700 AM	57	1025	M	E	pool

7215	lead ds>	5/15/1990	700 PM					acc chan
7216	us trap	5/15/1990	700 AM	58	1400	M	E	pool
7216	stand	5/15/1990	700 PM					retnr
7217	us trap	5/15/1990	700 AM	51		M	E	pool
7217	stand	5/15/1990	700 PM					retnr
7218	us trap	5/15/1990	700 AM	55		M	E	pool
7218	ds trap	5/16/1990	700 PM				S	acc chan
7219	us trap	5/15/1990	700 AM	50		F	S	pool
7219	lead ds>	5/15/1990	700 PM					acc chan
7220	lead ds>	5/15/1990	700 AM				S	acc chan
7220	us trap	5/15/1990	700 AM	65	1775		S	pool
7221	us trap	5/15/1990	700 AM	43	625	F	R	pool
7221	steep	5/15/1990	700 PM					retnr
7222	us trap	5/15/1990	700 AM	53	1300	F	R	pool
7222	steep	5/15/1990	700 PM					retnr
7223	us trap	5/15/1990	700 AM	54		M	E	pool
7223	ds trap	5/16/1990	700 AM				S	acc chan
7224	us trap	5/15/1990	700 AM	66		M	R	pool
7224	steep	5/16/1990	700 AM			M	R	retnr
7224	ds trap	5/20/1990	700 AM				R	acc chan
7225	us trap	5/15/1990	700 AM	46			S	pool
7226	us trap	5/15/1990	700 AM	60	2100		S	pool
7226	ds trap	5/17/1990	700 AM				S	acc chan
7227	us trap	5/15/1990	700 AM	52	950	M	E	pool
7227	ds trap	5/16/1990	700 AM				S	acc chan
7228	us trap	5/15/1990	700 AM	57	1350	M	E	pool
7228	ds trap	5/16/1990	700 PM				S	acc chan
7229	us trap	5/15/1990	700 AM	64		F	R	pool
7229	stand	5/15/1990	700 PM					retnr
7230	ds trap	5/15/1990	700 AM	41	550	M	S	acc chan
7231TAC	steep	5/15/1990	700 PM	41	500	M	S	retnr
7232TAC	stand	5/16/1990	700 AM	43	525	M	E	retnr
7233TAC	steep	5/16/1990	700 AM	52	1100	M	E	retnr
7234TAC	stand	5/16/1990	700 AM	49	850	M	R	retnr
7235	us trap	5/16/1990	700 AM	46	625	M	S	pool
7235	ds trap	5/17/1990	700 AM				S	acc chan
7236	us trap	5/16/1990	700 AM	53	1100	M	R	retnr
7236	retnr	5/16/1990	700 PM					pool
7236	ds trap	5/17/1990	700 AM				S	acc chan
7237	us trap	5/16/1990	700 AM	54	1300	M	R	pool
7237	ds trap	5/16/1990	700 PM			M	R	acc chan
7237	us trap	5/17/1990	700 AM			M	R	pool
7238	us trap	5/16/1990	700 AM	44	650	M	S	pool
7238	ds trap	5/16/1990	700 PM				S	acc chan
7239	us trap	5/16/1990	700 AM	58	1325	M	R	pool
7239	stand	5/16/1990	700 PM					timtri
7240TAC	steep	5/16/1990	700 PM	37	425	F	E	retnr
7241	lead us>	5/16/1990	700 PM	31	220	M	S	pool
7241	lead	5/21/1990	700 PM					dead
7242TAC	steep	5/17/1990	700 AM	42	625	M	R	retnr

7243	us trap	5/17/1990	700 AM	43	575		S	pool
7244	us trap	5/17/1990	700 AM	57	1300	M	E	pool
7245	us trap	5/17/1990	700 AM	51	950		S	pool
7245	steep	5/17/1990	700 PM				S	retnr
7247	us trap	5/17/1990	700 AM	43	625	M	E	pool
7247	steep	5/17/1990	700 PM				S	retnr
7248	us trap	5/17/1990	700 AM	62	1675	M	E	pool
7248	ds trap	5/19/1990	700 AM			M	R	acc chan
7251	us trap	5/17/1990	700 AM	66	2100	M	R	pool
7251	ds trap	5/18/1990	700 AM					acc chan
7252	steep	5/17/1990	700 PM				E or S	retnr
7252[1045]	us trap	5/17/1990	700 AM	55	1325	M	R	pool
7253	us trap	5/17/1990	700 AM	59	1800		S	pool
7253	ds trap	5/18/1990	700 AM				S	acc chan
7255	us trap	5/17/1990	700 AM	59	1350	M	E	pool
7255	ds trap	5/18/1990	700 AM				S	acc chan
7258	us trap	5/17/1990	700 AM	53	1125	M	R	pool
7258	ds trap	5/18/1990	700 AM				S	acc chan
7306	us trap	5/17/1990	700 AM	61	1950	M	S	pool
7316TDS	ds trap	5/17/1990	700 AM	25	90		I	acc chan
7317TDS	ds trap	5/17/1990	700 AM	60	1450			acc chan
7318TAC	stand	5/17/1990	700 PM	40	475		S	retnr
7319TAC	steep	5/17/1990	700 PM	37	400	M	E	retnr
7320TAC	steep	5/17/1990	700 PM	34	300	M	E or S	retnr
7326	pool	5/20/1990	700 AM					acc chan
7326TAC	steep	5/18/1990	700 AM	49	750		S	retnr
7327	us trap	5/18/1990	700 AM	65	1750	M	R	pool
7327	ds trap	5/18/1990	700 PM			M	R	acc chan
7332	us trap	5/18/1990	700 AM	45	900		S	pool
7332	pool	5/20/1990	700 AM					acc chan
7333	us trap	5/18/1990	700 AM	55	1200	M	R	pool
7333	ds trap	5/20/1990	700 AM			M	E	acc chan
7334	us trap	5/18/1990	700 AM	51	1000		S	pool
7334	steep	5/18/1990	700 PM				S	retnr
7335	us trap	5/18/1990	700 AM	47	750		S	pool
7335	ds trap	5/20/1990	700 AM				S	acc chan
7337	us trap	5/18/1990	700 AM	59	1800	M	E or S	pool
7337	ds trap	5/20/1990	700 AM				S	acc chan
7338	us trap	5/18/1990	700 AM	55	1100		S	pool
7338	ds trap	5/20/1990	700 PM				S	acc chan
7352	us trap	5/18/1990	700 AM	44	900	M	S	pool
7352	ds trap	5/20/1990	700 AM				S	acc chan
7354	us trap	5/18/1990	700 AM	44	650	F	S	pool
7354	ds trap	5/20/1990	700 AM				S	acc chan
7363TDS	ds trap	5/18/1990	700 AM	46	775		S	acc chan
7364TAC	stand	5/18/1990	700 PM	52	1025	M	R	retnr
7365	us trap	5/19/1990	700 AM	58	1700	M	E	pool
7365	ds trap	5/20/1990	700 AM				E	acc chan
7367	ds trap	5/20/1990	700 AM					acc chan
7367TDS	ds trap	5/19/1990	700 AM	66	2000	F	S	acc chan

7371TDS	ds trap	5/20/1990	700 AM	51	1650	M	S	acc chan
7372(1080)	ds trap	5/20/1990	700 AM	61	2200	M	E	acc chan
7377TDS	ds trap	5/20/1990	700 PM	59	1400	M	R	acc chan
7383TDS	ds trap	5/21/1990	700 AM	51	900	M	R	retnr
7384TDS	ds trap	5/21/1990	700 AM	39	450	M	R	retnr
7393TDS	ds trap	5/21/1990	700 AM	58	1700	M	R	acc chan
7394TDS	ds trap	5/21/1990	700 AM	47	800	M	R	acc chan
no tag	pool	5/20/1990	700 PM	63	2200	F	S	dead

Appendix 11. Tagged fish, miscellaneous species, Siisiip fishways, 1990

Tag Number	Species	Capture Location	Date	Time	Fork Length (cm)	Weight (g)	Sex	Repro-ductive Condition	Release Location
7211	Y Perch	ds trap	5/14/1990	930 AM	21	125	M	E	acc chan
finclip	Burbot	us trap	5/16/1990	830 AM	16	20	I		acc chan
7257	Walleye	us trap	5/17/1990	830 AM	45	1125	M	E	pool
7257	Walleye	ds trap	5/18/1990	930 AM				S	acc chan
7382	N R Sucker	gill net	5/20/1990	1045 AM	39	1100	M	S	acc chan

Appendix 12. Comparison of fork lengths of northern pike ascending the Siisiip fishways, Experiment Two, 1990.

a) Ascents of standard Denil versus steeppass fishway

	Mean Fork Length (cm)	n	t	Critical Value	Significance
Standard Denil	50.2	11	1.040	2.048	NS
Steeppass	46.9	19			

b) Ascents of ascending and nonascending pike, fishways combined

	Mean Fork Length (cm)	n	t	Critical Value	Significance
Ascending	48.1	30	2.322	1.990	*
Nonascending	53.0	52			

c) Pike ascending fishways at low flow versus pike ascending fishways at high flow

	Mean Fork Length (cm)	n	t	Critical Value	Significance
Low flow ascents	50.8	15	1.80	2.048	NS
High flow ascents	45.5	15			

d) Pike ascending either fishway at high flow versus nonascending pike

	Mean Fork Length (cm)	n	t	Critical Value	Significance
High flow ascents	45.5	15	2.820	2.000	**
Nonascents	53.0	52			